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Engineering Design File

PROJECT NO. 22901

TSF-09/18 V-Tank Contents Removal and Site Remediation

Idaho National Engineering and Environmental Laboratory

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The materials/corrosion evaluation indicated that 304L can be used for the Fenton system reactor at the boiling point if nitrates are used as passivating agents. Agitators can suspend the mean particle size using less than 5 horsepower motors. The air sparge-agitator system was designed based on standard methods and vendor information. The recirculation pumps by themselves may not be able to provide sufficient suspension of the mean particle size. However, they can provide backup and additional suspension to the agitators. The pumps can also provide 60 psig of discharge head at 50 gpm flow.

6. Review (R) and Approval (A) and Acceptance (Ac) Signatures:
(See instructions for definitions of terms and significance of signatures.)

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TABLES

ACRONYMS

E-CTFE	Halar, ethylene-chlorotrifluoroethylene copolymer
EDF	engineering design file
ES-CO/R/S	ex situ chemical oxidation/reduction/stabilization
HDPE	high-density polyethylene
MMPD	mass mean particle diameter
OU	operable unit
PSD	particle size distribution
PTFE	Teflon, polytetrafluoroethylene
PVC	polyvinyl chloride
PVDF	Kynar, polyvinylidenefluoride
RI/FS	Remedial Investigation/Feasibility Study
SCC	stress corrosion cracking
TAN	Test Area North
TSF	Technical Support Facility
VOC	volatile organic compound

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TSF-09/18 V-Tank Contents Removal and Site Remediation

1. SCOPE AND SUMMARY RESULTS

- *Determine tank and other equipment materials of construction.*
    - Type 304L/316 stainless steel can be used up to the boiling point with application of nitrates as passivating chemicals. This mainly applies to the Fento process reaction tank. However, one or more of the consolidation tanks may be used to receive product and will also be protected. Other materials were addressed for various uses. Air sparge/agitation will remove significant amounts of volatile organic compounds (VOCs) providing a reduced chloride level and subsequent additional assurance of corrosion protection.
- *Determine agitation requirements including power and air sparging.*
    - A mixer/agitator was determined; a Chemineer 3GTA-5 is initially specified, < 5 horsepower. There is also a sparge ring with 50, 1/8-in. holes to deliver about 50 ft^3/min (standard) per tank maximum.
- *Determine pumping requirements for re-circulation and V-Tank flushing.*
    - A < 10 horsepower, solids handling pump is specified for providing flush pressure of 60 psig at 50 gpm and > 100 gpm at recirculation system head loss. It is expected that this pump will have enough head and capacity to provide flow to the process and stabilization.
- *Determine the condition of the V-Tanks based on estimates of corrosion.*
    - The current state of the V-Tanks is such that there is a possibility of loss of strength at the liquid interfaces and the bottoms from stress corrosion and/or pitting. There is potential for stress corrosion cracking (SCC) in other stressed areas of the tanks. The risk is that one or both of these areas would be failure points upon lifting. However, the lifting method will ensure the bottoms are supported. The general corrosion rate is conservatively estimated as 1.0 mil/yr maximum.

2. INTRODUCTION

An accelerated process for destruction and/or removal of hazardous organic compounds from V-Tank liquids was previously determined to consist of ozonation plus sonication in recirculating flow systems.[a] However, a Fenton process has become available that will be used in stead. The process after receiving the wastes is shown in Figure 1. Note that Figure 1 has a valve for directing water from the supernate tank back to the flush system for flushing the V-Tanks. There will be three consolidation tanks but only one will be used for supernate collection and V-Tank flushing prior to equalization.[b]

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a. Ashworth, S.C., Ozone Treatment (Oxidation) for Tanks V1, 2, 3, and 9, EDF-4393.

b. Note that this EDF assumes that tank contents will be equalized prior to treatment.

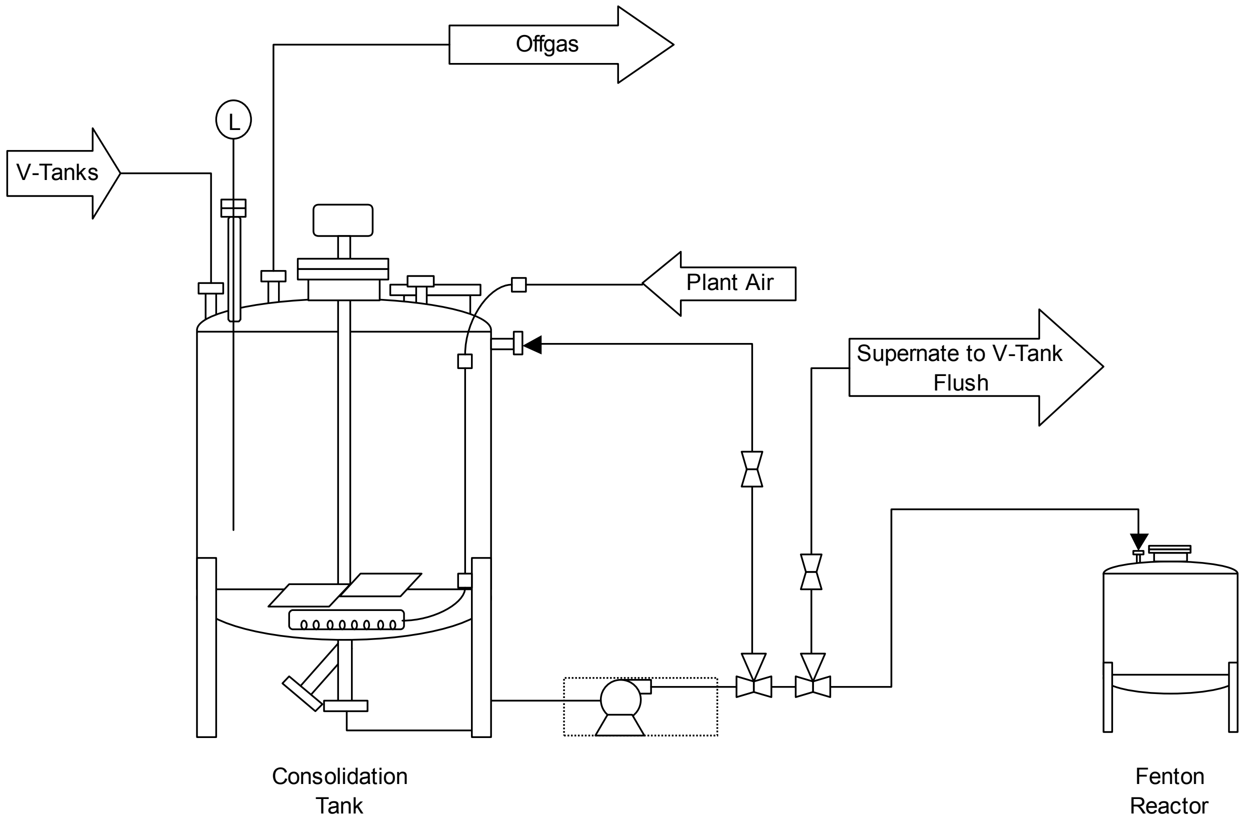


Figure 1. Consolidation Tank System.

Basically, this engineering design file (EDF) is concerned with the consolidation tanks and operations thereof. However, V-Tank liquid removal information is provided to enhance the consolidation logic for this EDF. Also, there are potentially important interfaces with the Fenton reactor. The plan is to separately remove sludge and supernates from the V-Tanks and consolidate into two, new 8,000 gal tanks. One of the consolidation tanks is used to collect supernates while the other will collect most of the sludges. The supernate will be used for further flushing/cleanout of the V-Tanks, hence the additional 3-way valve[c] shown in Figure 1. After this process, the tanks will be equalized to ensure that their bulk, average properties are commensurate. The new tanks need to be corrosion resistant to the worse case liquid/vapor and be able to provide suspension to the particles and prevent settling out while providing flow for process feed and re-circulation. It is also desired to have the option of an air sparge system for the removal via stripping of VOCs.

3. BACKGROUND

The four stainless steel tanks collectively known as the “V-Tanks” were installed at the Test Area North (TAN) as part of the system designed to collect and treat radioactive liquid effluents from TAN operations. The V-Tanks are underground stainless steel tanks associated with Operable Unit (OU) 1-10. These four tanks are identified as Tanks V-1, V-2, V-3, and V-9, with V-1, V-2, and V-3 identical in shape and size and V-9 having a unique, smaller shape (see Figure 2).

c. None of this constitutes title design but illustrates how process might be achieved.

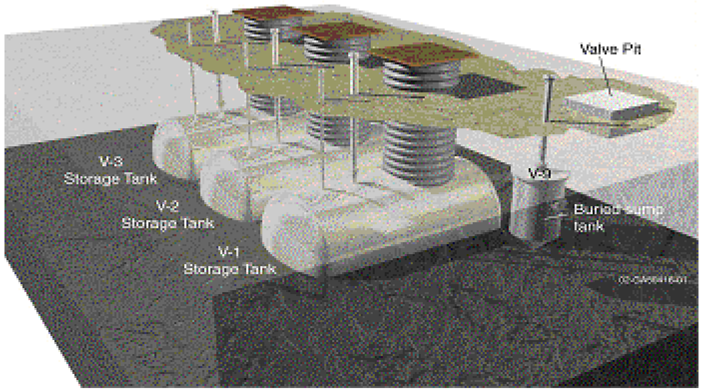


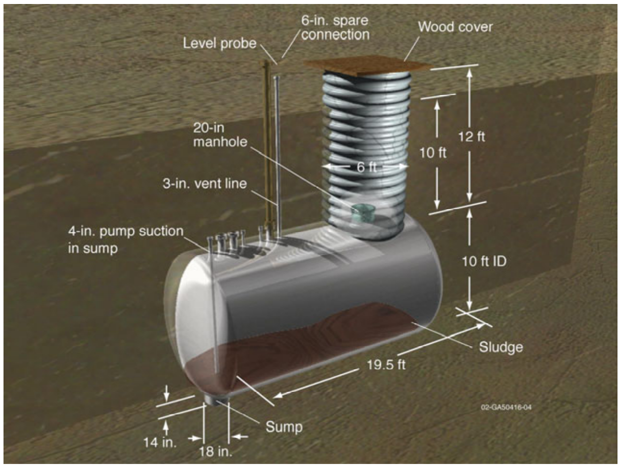
Figure 2. V-Tank ISO.

Tanks V-1, V-2, and V-3 were used for storage, while Tank V-9 was used as a primary separation tank to separate sediment and sludge from the liquid waste before transferring that waste to V-1, V-2, or V-3. Each of the V-Tanks currently contains a liquid and sludge layer, and all of the V-Tanks lack secondary containment. The tops of Tanks V-1, V-2, and V-3 are approximately 10 ft below grade, while the top of Tank V-9 is approximately 7 ft below grade. Tank V-9 is within Technical Support Facility (TSF) 18, while Tanks V-1, V-2, V-3, are within TSF-09.

The V-Tanks and associated piping were installed in 1953 and became operational in 1958. The tanks were designed to collect and store liquid radioactive waste at TAN. The waste was stored in the underground tanks then treated in the evaporator system located in TAN-616. Tanks V-1 and V-3 became inactive in the early 1980s. Tank V-2 was taken out of service in 1968 after a large quantity of oil was discovered in the tank. The oil was removed in 1981. In 1982, the excess free liquid was removed from the V-Tanks. Additional wastewater was reportedly added to Tank V-3 through 1985. Starting in 1985, all low-level radioactive waste at TAN was rerouted to the TAN-666 tanks through a piping modification in the TAN-1704 valve pit. The piping modification stopped intentional discharge to the V-Tanks in 1985. There is no evidence that sludge accumulating in the tanks was removed during or after site operations.

Tanks V-1, V-2, and V-3 are stainless steel tanks measuring 3 m (10 ft) in diameter, 5.9 m (19.5 ft) long, and buried approximately 3 m (10 ft) below ground surface (see Figure 3). The tanks have 50.8-cm (20-in.) manholes that are accessible through 1.8-m (6-ft) diameter culverts installed in 1981. Each tank is equipped with three subsurface influent lines and one subsurface effluent line. The tanks received radioactive wastewater via an influent line from Tank V-9. The remaining influent lines include a caustic line used to neutralize the waste prior to transfer to TAN-616 and a return flow line from the TAN-616 pump room. Tank V-3 has an additional inlet line from the TAN-615 east and west sumps. A single effluent line on each tank is routed to the TAN-616 pump room and evaporator system.

Liquid level measurements, recorded since April 1996, track the fluid levels in V-1, V-2, and V-3. Measurements since 1996, and anecdotal information preceding 1996, indicated an increase in the liquid level in Tank V-3 during the spring. This tank level stopped increasing in 2001. All lines, valves, and drains associated with the TSF-09 tanks are either plugged or identified as inactive; therefore, the increase is believed to be from spring snowmelt and runoff entering the tank through the manway above the entrance to Tank V-3. Liquid level measurements in Tanks V-1 and V-2 have remained relatively constant.



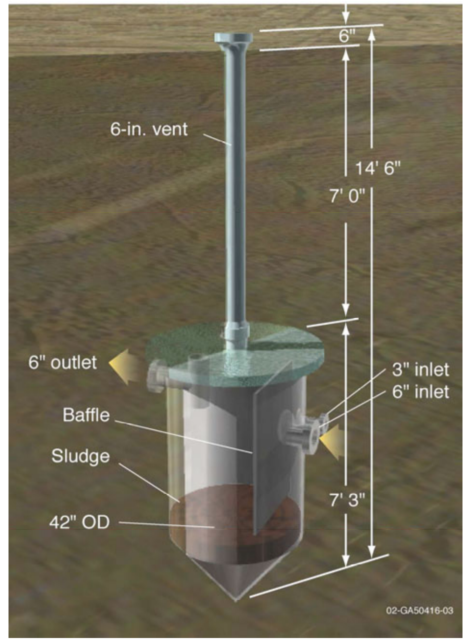


Figure 3. Tanks V-1, V-2, V-3, and V-9 (right).

The volume of liquid and sludge in the V-Tanks has been estimated based on the results of the 1996 RI/FS sampling. Table 1 summarizes the capacities and current contents (i.e., reflecting liquid level increases since the RI/FS) of the four V-Tanks.

Table 1. V-Tank capacities and current contents (gallons).

Tank	Capacity	Liquid Volume	Sludge Volume	Total Volume
V-1	10,000	1,164	520	1,684
V-2	10,000	1,138	458	1,596
V-3	10,000	7,660	652	8,312
V-9	400	70	250	320
Total	30,400	10,032	1,880	11,912

Based on 1980 x-ray diffraction data, the 1993 Track 2 investigation, and the 1996 Remedial Investigation/Feasibility Study (RI/FS) sampling results, the major V-Tank constituents[d] are shown in Table 2.[e]

A pre-conceptual design study addressed seven possible alternatives for remediating the V-Tanks and treating the contaminants shown in Table 2. A subsequent Technical Evaluation study selected ex situ chemical oxidation/reduction/stabilization (ES-CO/R/S) as the preferred remediation technology (prior to this work). Subsequently, a conceptual design report, *Conceptual Design Report for Ex Situ Chemical*

d. The data in Table 2 differ from data in previous V-Tank documents because it reflects recent validation efforts documented in EDF-3791.

e. The concentrations are total concentrations.

Oxidation/Reduction and Stabilization of the V-Tanks at Waste Area Group 1, Operable Unit 1-10, (INEEL 2003), was written.

Table 2. V-Tank characterization.

	Sludge (mg/kg)	Liquid (mg/L)
Inorganic Components, Cations		
Al	4.19	0.81
Ba	2.36	0.46
Be	0.28	0.05
Ca	250.26	48.42
Cd	0.17	0.03
Co	0.44	0.09
Cu	0.40	0.08
Fe	9.34	1.81
Mg	117.97	22.83
Mn	6.18	1.20
Pb	0.93	0.18
Hg	0.26	0.05
Ni	2.03	0.39
K	874.96	169.30
Ag	0.06	0.01
Na	1440.58	278.74
Tl	0.08	0.02
Sn	0.01	0.00
V	0.58	0.11
Zn	40.73	7.88
Inorganic Components, Anions		
Sb	1.15	0.22
As	0.08	0.01
B	65.27	12.63
Br	13.84	2.68
Cl	660.76	127.85
Cr	0.46	0.09
F	60.55	11.72
Nitrate	5.13	0.99
Nitrite	48.45	9.37
Phosphate	29.20	5.65
P	7.33	1.42

Table 2. (continued).

		Sludge (mg/kg)	Liquid (mg/L)
	Se	0.08	0.02
	Si	49.80	9.64
	Sulfate	122.46	23.70
VOCs			
	bromomethane	2.47E+01	1.65E-01
	chloroethane	9.56E+01	3.30E-01
	chloromethane	1.59E+01	5.66E-02
	1,2-dichlorobenzene	6.95E+01	2.46E+00
	1,3-dichlorobenzene	9.68E+01	2.52E+00
	1,4-dichlorobenzene	1.03E+02	2.52E+00
	1,1-dichloroethane	2.10E+01	9.69E-02
	trans-1,2-dichloroethylene	3.52E+01	4.32E-01
	methylene chloride	9.56E+01	6.05E-01
	PCE	1.14E+03	3.50E-01
	1,2,4-trichlorobenzene	9.81E+01	2.52E+00
	TCA	5.30E+02	8.25E-01
	TCE	4.61E+03	4.31E+00
	vinyl chloride	4.71E+01	2.51E-01
SVOCs			
	Aroclor-1260	1.44E+02	2.53E-01
	bis(2-ethylhexyl)phthalate	3.71E+03	1.54E-01
	2,4-dimethylphenol	1.18E+02	2.52E+00
	4,6-dinitro-2-metylphenol	5.98E+02	4.86E+00
	di-n-octylphthalate	1.20E+02	2.52E+00
	2-methylnaphthalene	3.31E+01	2.52E+00
	2-methylphenol	1.38E+02	2.53E+00
	4-methylphenol	1.18E+02	2.53E+00
	naphthalene	9.20E+01	2.52E+00
	4-nitrophenol	5.98E+02	4.86E+00
	phenol	1.02E+02	2.52E+00
	pyrene	1.20E+02	5.87E-01

4. MATERIALS OF CONSTRUCTION

Revision 0 of this EDF focused on determining materials for the consolidation tanks based on using them as part of the process system. Since then, the process has changed and the consolidation tanks are no longer used directly in the treatment. However, being 304L, as determined in Revision 0, they still need to be resistant to chlorides and one or more of them may be used to receive product from the treatment process. Also, the treatment tanks are 304L and need to be chloride resistant at the boiling point, approximately 95°C.

4.1 Chloride

Chloride is present in the V-Tanks, averaging about 100 mg/L (final could be as high as 187 mg/L). Chloride could increase as a result of the VOC oxidation if not prestripped. The current stainless steel apparently works well at a lower temperature, as the liquid has not leaked out of the V-Tanks. However, at temperatures above 60°C (140°F), chlorides are known to cause excessive corrosion especially in pitting and stress corrosion cracking (SCC) of stainless steels (mainly austentites) (Davis et al. 1992; Uhlig 1985). Figure 4 shows that 304 will pit at 0.02% Cl^- at 50°C. The corrosion rate of 316 in a marine environment at ambient temperature (as well as many other austentites) is < 0.001 mil/yr (Davis et al. 1992). Figure 5 shows that 304/316 will not crack at any chloride if the temperature is less than 50°C. One of the other actions that has been done to decrease pitting potential in stainless is to add nitrates. Nitrates (e.g., $NaNO_3$) can be added to consolidation tanks or the reaction vessel to elevate the NO_3^-/Cl^-ratio. Previous work has shown that 0.4 M NO_3^- provided passivation towards 304L at 1000 ppm Cl^-. Therefore, $NaNO_3$ will be used to provide passivation.

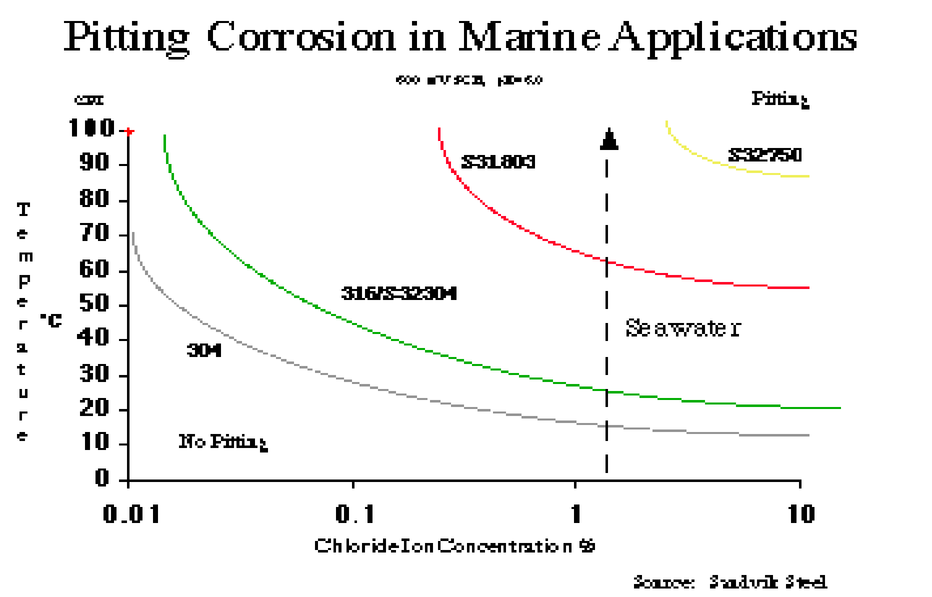


Figure 4. Pitting corrosion in marine applications.

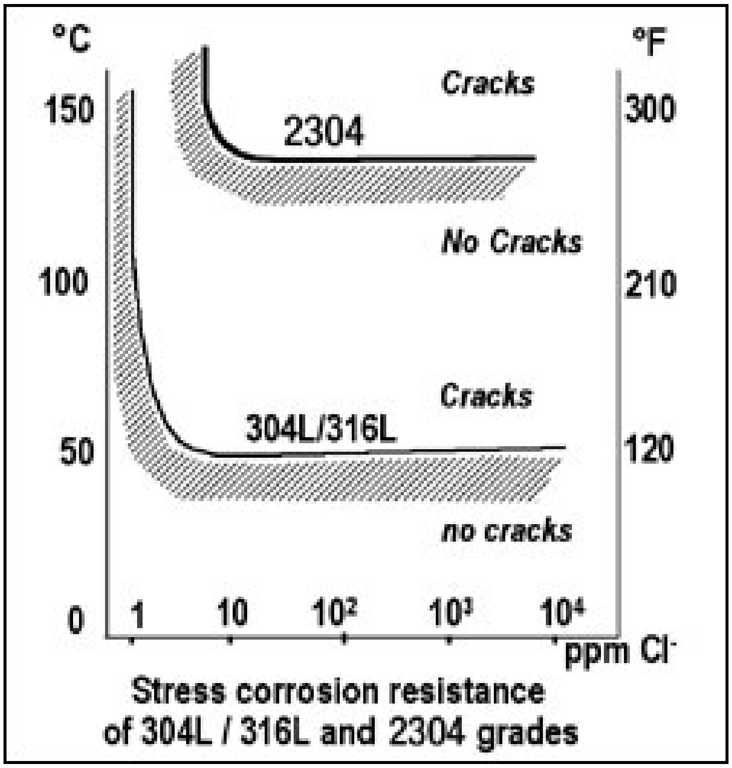


Figure 5. 2304 SCC.

4.2 pH

The pH of the process will be adjusted to approximately 3.5. The presence of chlorides would normally impact the corrosion of 304L at this pH. However, with the passivating nitrates, little corrosion is expected.

4.3 Oxygen

Oxygen is generated in the process by the degradation of hydrogen peroxide (H_2O_2). The combination of oxygen and chlorides leads to a corrosive environment for 304L. However, as with pH, the passivating nitrates provide a protective film and therefore, corrosion resistance.

4.4 Chromium

There is some free chromium in the liquid phase of the V-Tank wastes. Chrome is oxidized under the expected ReDox potential. The Cr^{+6} then oxidizes the Cr^{+3} in the steel thereby leading to grain boundary disruption, i.e.:

$$Cr_{aq}^{+3} = Cr_{aq}^{+6} + 3e^{-}$$

$$Cr_{aq}^{+6} + \overline{Cr}^{+3} = Cr_{aq}^{+3} + \overline{Cr}^{+6}$$

There is little that can be done against this occurrence with stainless systems. However, stainless should be adequate for the short operational duration.

4.5 Plastics

Plastics will be used for various items in the system. In general, plastics have excellent resistance to most chemicals. They vary in their resistance to radiation. Kynar (PVDF) has good radiation resistance to 10^8 rads (see Table B-2 in Appendix B).[f] Halar also has good radiation resistance up to 2×10^8 rads.[g] High-density polyethylene (HDPE) is also good at least to 10^8 radiation-absorbed dose and in fact has increased strength and lower leachability as a result of γ-induced cross-linking (Oh 2001). If the amount of radiation is based on 1 R/hr, the time it will take to absorb 10^8 rads is far greater than the project life. However, HDPE has poor resistance to ultraviolet radiation and needs a stabilizer if exposed outside for extended periods. There is no impact of radiation at the expected levels on stainless steel or any other of the metals. Teflon that could be used in some of the miscellaneous materials like pump seals, has a lesser radiation resistance (28% loss in strength at 58.3 kGy[h] equating to almost 10^7 rad) as found by experiment with x-rays during Hubble telescope experiments.

4.6 Combination

The only method to determine the effects of a combination of the chemicals and γ radiation is testing. Material testing is not practical for this project so it will not be known whether interactive effects will occur. However, based on the short operational time frame and the good resistance of the materials selected, the short operational duration, and the environmental conditions recommended, the risk of failure is minimal.

4.7 Gas-Phase

Gas phase can also be corrosive particularly at liquid-gas interfaces. An examination of the information available on Kynar indicates that it is also good for gas-phase components including chlorine and solvents (little chloride or radiation will be in the gas phase except by splashing). However, gas-phase chlorine presents a problem for stainless steel. Small amounts of chlorine could be released during the Fenton process. Type 316 had a rate of 31 mil/yr in water saturated chlorine gas. At a pH of 3.5, a fairly high chlorine concentration in the gas-phase could occur. However most of these would come from the liquid-phase oxidation of VOCs that will be stripped prior to processing. The following reactions occur with chlorine systems:

$$Cl_{2g} = Cl_{2l}$$

$$Cl_{2l} + H_2O = HCl + HOCl$$

$$2NaOH + HCl + HOCl = NaCl + NaOCl$$

f. http://nepp.nasa.gov/npsl/Wire/insulation_guide.htm.

g. http://www.advancedproducts-1.com/Halarc.htm.

h. http://www.lerc.nasa.gov/WWW/epbranch/other/hstabls.htm.

These are solved for in Appendix A-1. The solution indicates that the gas phase chlorine could be excessive if the pH is 3.5. However, since the chlorinated VOCs are stripped out, the chlorine is insignificant as shown in Appendix A-1.

4.8 Other Equipment

The piping to the consolidation tanks from the V-Tanks (i.e., outside the containment used for transfer) was selected to be high-density polyethylene (HDPE). HDPE is satisfactory for use with chlorides at ambient and elevated temperature[i] and has a fair rating for solvents. Chlorides, solvents, and radiation are the working solution for the transfer piping. Other materials selection will be on a case-by-case basis.

5. PARTICLE SIZE AND DENSITY

The particle size distribution (PSD) is required to determine solids suspension equipment, e.g., agitators and recirculation pumps. It was determined[j] that sizing will be based on the mass mean particle diameter (MMPD) as opposed to the largest particle. Data is available from two samples for Tank V-9 (DOE-ID 2002) but is sketchy for Tanks V-1, -2, and –3. The data from V-9 ranged from 30 to > 400 mesh so the largest size was assumed to be 30 mesh (595 μm) and smallest (>400 mesh) was considered to be 10 μm. The PSD data for the other tanks was determined[k] as 86% < 400 mesh (considered to be 10 μm), 11% > 30 mesh (considered to be 595 μm), 30 mesh < 1% < 50 mesh (considered to be 297 μm), and the rest between 50 and 400 mesh (considered to be equally distributed at 0.5% for 37, 74, 149, and 210 μm). The translations are shown in Table 3 for Tank V-9 and Table 4 for Tanks V-1, V-2, and V-3. Based on using weighted averages of the tanks, the overall MMPD is 144 μm as shown Table 5.

The density ranges widely for the tanks. For power equipment sizing, the density of particles in Tank V-9 was considered worse case. All of the density data from sampling was averaged to arrive at a density of 1.46 ± 0.53 kg/L. The 1.46 value is the user or expectation value to be used in calculations.

Table 3. Tank V-9 mesh to PSD.

Tank V-9 Screen Mesh Size to Particle Distribution				
Mesh	%	%	%	um
< 30	65.8	70	67.9	595
< 50	8.4	7.9	8.15	297
< 70	1.7	1.8	1.75	210
< 100	3.4	3.5	3.45	149
< 200	4.4	5	4.7	74
< 400	3.5	3.1	3.3	37
> 400	12.7	8.7	10.7	10
		Translation →		

i. http://www.bpsolvaype.com/na/upload/techpub_n21.pdf.

j. Project meeting on February 12, 2004.

k. email from Rick Farnsworth, INEEL, February 19, 2004.

Table 4. Tanks V-1, -2, and –3 Mesh to PSD.

Tanks V-1,-2,-3 Screen Mesh Size to Particle Distribution			
Mesh	%	%	um
< 30	11	11	595
< 50	1	1	297
< 70		0.5	210
< 100	2	0.5	149
< 200		0.5	74
< 400		0.5	37
> 400	86	86	10

Translation

Table 5. V-Tank MMPD determination.

	mass.kg					
	1378.00	2001.46	1768.68	2512.42	7660.56	
	TankV-9	Tank V-1	Tank V-2	Tank V-3		
Um	%	%	%	%	wt fr	wf*dp
595	67.9	11	11	11	0.21	126.35
297	8.15	1	1	1	0.02	6.79
210	1.75	0.5	0.5	0.5	0.01	1.52
149	3.45	0.5	0.5	0.5	0.01	1.54
74	4.7	0.5	0.5	0.5	0.01	0.93
37	3.3	0.5	0.5	0.5	0.01	0.37
10	10.7	86	86	86	0.72	7.25
					1.00	144.74

6. AGITATOR SIZING

It has been determined that the agitator will be designed based on the MMPD from all of the tanks equalized. First, the agitator was scoped using correlations as shown in Appendix A-2. Next, the basic information was provided to two vendors, Lightnin and Chemineer, for their final sizing and power requirements. The agitator design is integral with tank design so the tank dimensions were estimated. The correlations (Harnby et al. 1992) used determined the minimum impeller speed to provide suspension of a 144 μm particle of density 1.46 kg/L. The viscosity was estimated to be 1.0 centipoise (cP) or 1.0 centistoke (cS). No viscosity data were available so this estimate is based on the fact that water at ambient conditions is 1.0. The elevated temperature will decrease the viscosity but the TSS/TDS will tend to increase it. The results of the scoping estimates show that an agitator less than 5 horsepower will be sufficient as discussed in Appendix A-2. The vendor provided a recommendation for using the Chemineer 3GTA-5, 5-hp unit discussed in Appendix C. The agitator will require additional specification to ensure parts exposed to vapor/liquid are corrosion resistant and final adjustment for fitting to the final tank specification. This will be provided in the final equipment specification. A sparge ring is also included to provide a maximum 50 scfm per tank of air from a 100 psig plant air system.

7. RECIRCULATION PUMP SIZING

This task, using previously determined fluidic properties, determined the recirculation pump size. The design basis is to match two situations: 50 gpm at 60 psig discharge head pressure, and at least 100 gpm at the system head loss for recirculation processes. The pump calculations are discussed in Appendix A-3 and the vendor information is in Appendix C. The pump is a Goulds Model 3196 with a John Crane double mechanical seal designed for abrasive slurries as shown in Appendix C. The power requirements are 7.5-10 horsepower per pump, three pumps, one for each tank. The process system, to be determined later, has an unknown head loss so this pump may or may not be sufficient for the process. The pump requires a small amount of water to feed to the seals to prevent salting and early pump failure as shown in Appendix C.

These pumps, by themselves, will not provide suspension of the MMPD but provide backup to the agitators. Suspension of the MMPD via recirculation would require higher flow than the 100 gpm target and hence, higher power requirements as discussed in Appendix A-3. One caveat needs to be emphasized for this pump; the presence of gravel could severely damage it based on INEEL experience.[1] However, this is not anticipated to be a major problem as the pumps can be easily changed out. It is also desired to provide enough flow for the process requirements and stabilization (e.g., grouting). It is anticipated, but not known, that the head and flow will be adequate for the process and grouting.

8. V-TANK CONDITION

It is difficult to assess for certain what condition the tanks are in. Typical average, general corrosion rates are less than 0.1 mil/yr in quiet seawater (Fontana 1986). To be conservative, a general rate of 1.0 mil/yr is specified. Some of the potential corrosion mechanisms include galvanic corrosion at the air-water interface and pitting, particularly on the tank bottom where particles have settled. The air-liquid interface and the bottom are likely the weakest points. The ASM Corrosion Manual (Davis et al. 1992) indicates negligible corrosion of the austentites in marine atmospheres and ambient conditions. History of buried carbon steel shows 95% of material has insignificant corrosion. For stainless steel, history shows insignificant corrosion for soils. Since this soil is dry and not in a known corrosive environment, there should be little corrosion on the soil side. The general corrosion outside and inside is likely negligible except for sidewall pitting of about 1 mil in depth. However, lifting will likely be accomplished by slinging underneath the tanks and will therefore pose little risk to yielding at the weak points during the lifts. This analysis is speculative and requires actual tank inspection to determine the actual condition.

The following are the half-cell reactions for the iron in stainless steel:

Cathode

$$2e^{-} + 1/2O_2 + H_2O = 2OH^{-}$$

Anode

$$Fe = Fe^{+2} + 2e^{-}$$

1. EDF-4418, "Mockup Test Report for Closure of CPP-603 Basin Water Treatment Vessels," Draft.

The electrons flow through the metal to the interface rich in oxygen and water corroding the anode. The loss of metal can thin or weaken the interface. Since it is not known what the original thickness the V-Tanks are, it is difficult to assess. However, assuming an original of 1/4 in., a 1 mil/yr rate would result in a final thickness of:

$$t_{fin} = 1/4in - 1mil/yr * (2004 - 1958)yr = 0.204\ in.$$

It is believed that this is conservative. Although the oxygen in the air leads to this corrosion, in stainless steel it also leads to protection, i.e., the oxide films formed provide a diffusion barrier retarding ferrous and other ions from reaching the surfaces.

9. UNCERTAINTIES AND RISKS

- The materials selection likely represents the biggest risk. Catastrophic failure of tanks would jeopardize the project objectives. However, based on the short operational duration and environmental conditions recommended, this risk is expected to be minimal.

- It is possible, but not highly likely, that the pumps selected will not meet the process needs. In that case, the process could provide additional pumping. Also, the presence of large gravel could damage the pumps. However, there is no reason to expect the presence of large quantities of gravel and spare pumps will be on hand for replacement if this happens.

- Since the agitation is based on the mmpd and not the largest particles, there will likely be some slip. This is not expected to lead to plugging as the suction line of the re-circulation pumps will re-accelerate the larger particles. The viscosity was estimated. Therefore, if lower than the estimate, suspension will be enhanced by the agitator but less so by the pump. Conversely, if the viscosity is higher, the agitator will be less effective but particle suspension will be enhanced by pumping since settling is slower.

- Lastly, the design and selection by this EDF depends on the data provided. If this data is incorrect, there are serious risks in many of the areas.

10. CONCLUSIONS

The tanks and ancillaries can also be constructed of Type 304L/316 by using nitrates as a passivating agent. This is primarily aimed at protecting the Fenton reactor but also protects the consolidation tanks if used for product collection. There is still risk with these materials but the short operational duration minimizes them.

Agitators can suspend the mean particle size using less than 5-hp motors. The associated ring sparge system does not hinder particle suspension and provides enough mass transfer to strip liquid-phase VOCs in very short batch-times (see EDF-4956).

The re-circulation pumps by themselves may not be able to provide sufficient suspension of the mean particle size. However, they can provide backup and additional suspension to the agitators. The pumps can also provide 60 psig of discharge head at 50-gpm flow.

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Appendix A-1

Chlorine Determination

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Appendix A-1, Chlorine Determination

Determine pH range and effects of stripping VOCs to keep gas phase chlorine to insignificant levels (< 10 ppm$_v$)

Assumption: All chlorinated hydrocarbons are oxidized in the liquid phase producing chloride and chlorine. This estimates is based on worst case, air stripping will remove the chlorine producing VOCs.

Physical - chemical reactions

$Cl_{2g} = Cl_{2l}$

$Cl_{2l} + H_2O = H^+ + Cl^- + HOCl$

$HOCl = H^+ + OCl^-$

The K-values are from Metcalf & Eddy (Tchobanoglous et al, 1991)

$$K_1 = \frac{H \cdot Cl HOC}{Cl_{2l}} = 4.5 \cdot 10^{-4} \frac{mol^2}{L^2} \qquad K_1 := 4.5 \cdot 10^{-4} \frac{mol^2}{L^2}$$

$$K_2 = \frac{H \cdot OCl}{HOCl} = 2.9 \cdot 10^{-8} \frac{mol}{L} \qquad K_2 := 2.9 \cdot 10^{-8} \frac{mol}{L}$$

Total chlorine is known

$$Cl_{2\_tot} = Cl_{2l} + HOCl + OC$$

Let H^+ vary as parameter at various pH using pH = 7 as a baseline:

$$H_x := 10^{-7} \frac{mol}{L} \qquad pH := -\log\left(\frac{H_x}{1 \frac{mol}{L}}\right) \qquad pH = 7 \qquad OH := \frac{10^{-14} \frac{mol^2}{L^2}}{H_x}$$

$$Cl_{2\_tot} := 2538 \frac{mg}{L} \cdot \frac{1}{71 \frac{gm}{mol}} \qquad Cl_{2\_tot} = 0.036 \frac{mol}{L}$$

Note, If all chlorinated VOC's oxidized in liquid phase

Need one more equation: Cl = OCl^- + HOCl from reaction equations

System of equations

Original

Elimination

$$H_x \cdot OCl - K_2 \cdot HOCl = 0$$

$$HOCl = \frac{H_x \cdot OCl}{K_2}$$

$$Cl = OCl + HOC$$

$$H_x \cdot Cl \cdot HOCl - K_1 \cdot Cl_{21} = 0$$

$$Cl_{21} = \frac{H_x \cdot Cl \cdot HOCl}{K_1}$$

$$Cl_{2\_tot} = Cl_{21} + HOCl + OC$$

$$\frac{H_x \cdot \left(OCl + \frac{H_x \cdot OCl}{K_2}\right) \cdot \frac{H_x \cdot OCl}{K_2}}{K_1} + \frac{H_x \cdot OCl}{K_2} + OCl - Cl_{2\_tot} = 0$$

$$H_x^{\,2} \cdot OCl^2 \cdot K_2 + H_x^{\,3} \cdot OCl^2 + H_x \cdot OCl \cdot K_2 \cdot K_1 + OCl \cdot K_2^{\,2} \cdot K_1 - Cl_{2\_tot} \cdot K_2^{\,2} \cdot K_1 = 0$$

$$OCl^2 + \left(\frac{H_x \cdot K_2 \cdot K_1 + K_2^{\,2} \cdot K_1}{H_x^{\,2} \cdot K_2 + H_x^{\,3}}\right) \cdot OCl + \left(\frac{-Cl_{2\_tot} \cdot K_2^{\,2} \cdot K_1}{H_x^{\,2} \cdot K_2 + H_x^{\,3}}\right) = 0$$

$$a := 1 \qquad b := \frac{H_x \cdot K_2 \cdot K_1 + K_2^{\,2} \cdot K_1}{H_x^{\,2} \cdot K_2 + H_x^{\,3}} \qquad c := \frac{-Cl_{2\_tot} \cdot K_2^{\,2} \cdot K_1}{H_x^{\,2} \cdot K_2 + H_x^{\,3}}$$

$$b = 1.305 \times 10^3 \frac{mol}{L} \qquad c = -10.487 \frac{mol^2}{L^2}$$

$OCl := \frac{-b + \sqrt{b^2 - 4 \cdot a \cdot c}}{2a}$ $\quad$ $OCl = 8.036 \times 10^{-3} \frac{mol}{L}$

$HOCl := \frac{H_x \cdot OCl}{K_2}$ $\quad$ $HOCl = 0.028 \frac{mol}{L}$

$Cl := HOCl + OC$ $\quad$ $Cl = 0.036 \frac{mol}{L}$

$Cl_{21} := \frac{H_x \cdot Cl \cdot HOCl}{K_1}$ $\quad$ $Cl_{21} = 2.201 \times 10^{-7} \frac{mol}{L}$

Finally, determine the gas-phase chlorine using Henry's Law (Sander 1999):

$k_{H\_Cl2} := 9.5 \cdot 10^{-2} \frac{mol}{L \cdot atm}$ $\quad$ $H_{Cl2} := \frac{1}{k_{H\_Cl2}}$

$H_{Cl2} = 10.526 \frac{L \cdot atm}{mol}$ $\quad$ $P := 12.5 \ psi$ $\quad$ $P = 0.851 \ atm$

$y_{Cl2g} := \frac{H_{Cl2} \cdot Cl_{21}}{P}$ $\quad$ $y_{Cl2g} = 2.724 \times 10^{-6}$

In terms of ppm_V:

$y_{Cl2g\_ppmv} := y_{Cl2g} \cdot 10^6$ $\quad$ $y_{Cl2g\_ppmv} = 2.724$

So at pH = 7, there is insignificant gas phase chlorine. Now, provide plots for the pH range of 1 to 10. The 2 plots are shown in Figures A-1-1 and A-1-2. The results show that pH can decrease to approximately 6.5 before the vapor phase chlorine reaches 10 ppm.

Figure A-1-1

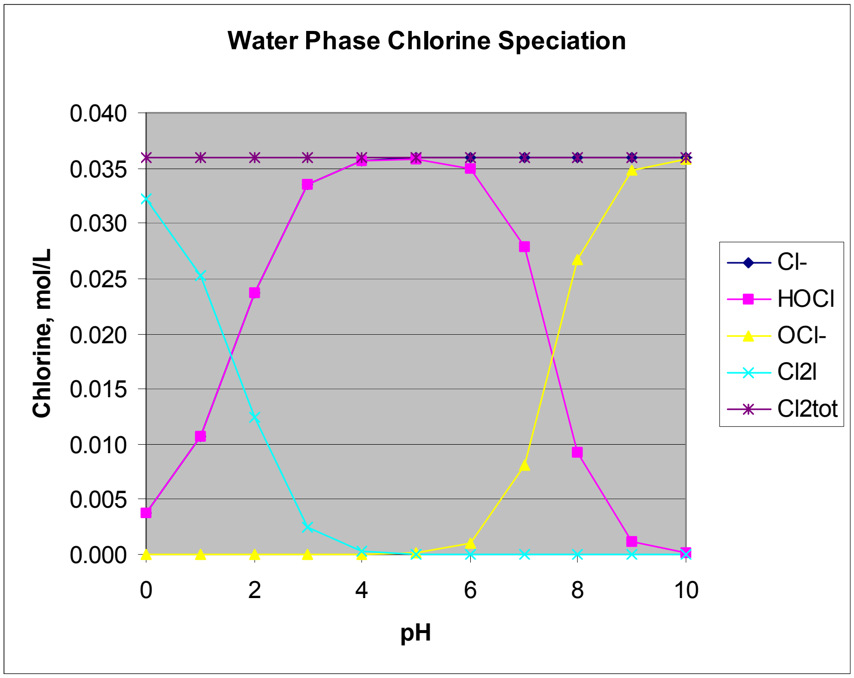
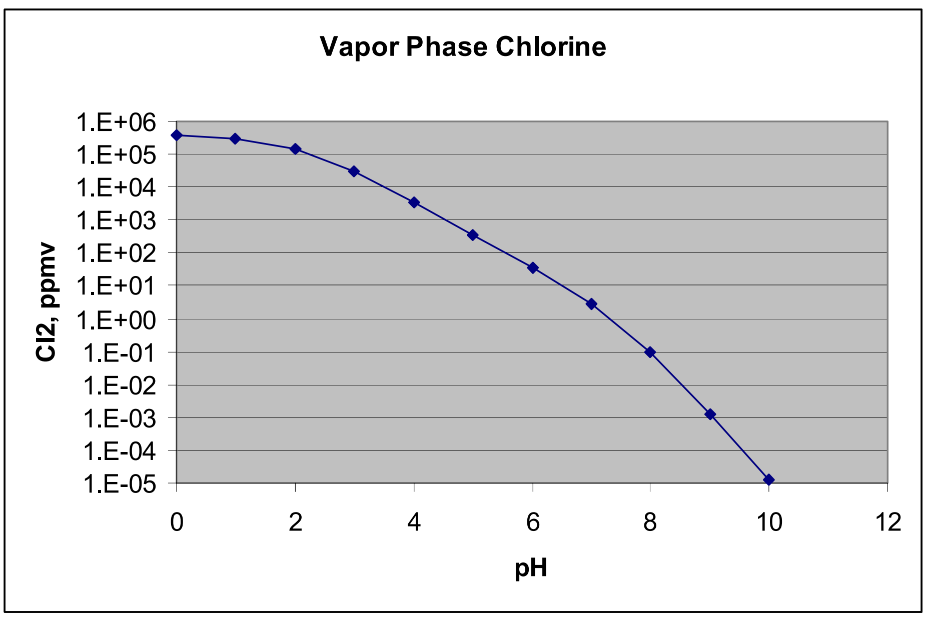


Figure A-1-2 if VOCs not pre-stripped



Repeat process assuming VOCs are stripped and only PCB contributes to chlorine. If the hydrogens shown in Figure A-1-3 equal the chlorines, HCl is formed, otherwise Cl_2 is formed. Assume the chlorines exceed the hydrogens by 2 as shown in Figure A-1-4.

Figure A-1-3

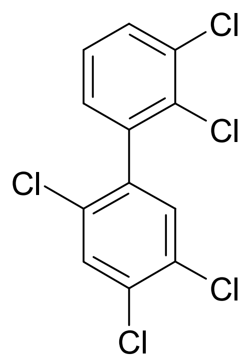
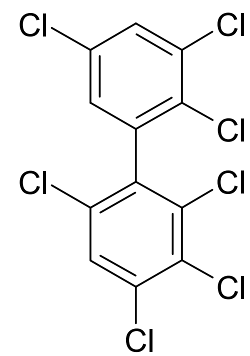


Figure A-1-4



$$C_{12}H_3Cl_7 + 51OH\bullet = 12CO_2 + 27H_2O + \frac{7}{2}Cl_2$$

$$MW_{PCB} := (12\cdot 12 + 3 + 7\cdot 35.5)\frac{gm}{mol}$$

$$C_{PCB\_tot} := 0.253\frac{mg}{L}\cdot\frac{1}{MW_{PCB}} \qquad Cl_{2\_tot} := C_{PCB\_tot}\cdot\frac{7}{2} \qquad pH := 3.5$$

$$H_x := 10^{-pH}\frac{mol}{L}$$

$$a := 1 \qquad b := \frac{H_x\cdot K_2\cdot K_1 + K_2^{\,2}\cdot K_1}{H_x^{\,2}\cdot K_2 + H_x^{\,3}} \qquad c := \frac{-Cl_{2\_tot}\cdot K_2^{\,2}\cdot K_1}{H_x^{\,2}\cdot K_2 + H_x^{\,3}}$$

$$b = 1.305\times 10^{-4}\frac{mol}{L} \qquad c = -2.679\times 10^{-14}\frac{mol^2}{L^2}$$

$$OCl := \frac{-b + \sqrt{b^2 - 4\cdot a\cdot c}}{2a} \qquad OCl = 2.053\times 10^{-10}\frac{mol}{L}$$

$$HOCl := \frac{H_x\cdot OCl}{K_2} \qquad HOCl = 2.239\times 10^{-6}\frac{mol}{L}$$

$Cl := HOCl + OCl$ $\qquad Cl = 2.239\times 10^{-6}\frac{mol}{L}$

$Cl_{2l} := \frac{H_x \cdot Cl \cdot HOCl}{K_1}$ $\qquad Cl_{2l} = 3.522\times 10^{-12}\frac{mol}{L}$

Finally, determine the gas-phase chlorine using Henry's Law (Sander 1999):

$k_{H\_Cl2} := 9.5\cdot 10^{-2}\frac{mol}{L\cdot atm}$ $\qquad H_{Cl2} := \frac{1}{k_{H\_Cl2}}$

$H_{Cl2} = 10.526\frac{L\cdot atm}{mol}$ $\qquad P := 12.5\ psi \qquad P = 0.851\ atm$

$y_{Cl2g} := \frac{H_{Cl2}\cdot Cl_{2l}}{P}$ $\qquad y_{Cl2g} = 4.359\times 10^{-11}$

In terms of ppm_v:

$y_{Cl2g\_ppmv} := y_{Cl2g}\cdot 10^6$ $\qquad y_{Cl2g\_ppmv} = 4.359\times 10^{-5}$

Therefore, based on pre-stripping the VOCs, the vapor phase chlorine is very small and of no concern.

NOMENCLATURE

a,b,c	Quadratic constants
H	Henry's constant
k_H	Inverse Henry's (i.e. solubility)
$K_{1,2}$	Equilibrium coefficients
P	Pressure
y_i	Mole fraction, ppm, gas

REFERENCES

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Appendix A-2

Agitator/Sparge Ring Design and Calculations

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Appendix A-2, Agitator and Sparge Ring Design and Calculations

Particle Density

$\rho_{part} := 1.46\frac{kg}{L}$ Average bulk density from V-9 data

The largest particle reported is 30 mesh and the estimated average mmpd is 144 μm (see EDF body).

$d_p := 144 \cdot 10^{-6} m$ Note, this is somewhat variable depending on the methods used as shwon in the report body. However, changes in some of the percentages have little affect on the mmpd.

Definitions

Power Number $P_o = \frac{P_{ow}}{\rho \cdot N^3 \cdot D_{imp}^{\ 5}}$

Reynolds Number (mixing) $Re = \frac{\rho \cdot N \cdot D_{imp}^{\ 2}}{\mu}$

Rev to Rad $Rev := 2 \cdot \pi \cdot rad$

The minimum impeller speed is (Harnby et al 1992):

$$N_{JS} = \frac{S_m \cdot \nu^{0.1} \cdot d_p^{\ 0.2} \cdot \left(g \cdot \frac{\Delta\rho}{\rho_L} \right)^{0.45} \cdot \chi^{0.13}}{D_{imp}^{\ 0.85}}$$

The S_m parameter is system specific and found via various vendor information. Harnby has some of these for Chemineer and Lightnin as well as others. The S's and P_o's are a function of λ/D and D_{imp}/D.

For a Chemineer HE3 (Harnby et al 1992)

$$\frac{\lambda}{D} = \frac{1}{4}$$

$$\frac{D_{imp}}{D} = \frac{1}{3}$$

$$P_o := 0.25$$

$$S_m := 7.2$$

For the system

$$g := 9.8\frac{m}{s^2}$$

$$\rho_s := \rho_{part}$$

$$\rho_L := 1\frac{kg}{L}$$

$$\Delta\rho := \rho_s - \rho_L$$

$\nu := 0.01\ \text{stokes}$ (Assumed)

$$\chi := \frac{7348\,kg}{10033\,L\cdot\rho_L}\cdot 100$$

Solids per solids-free liquid using the characterization data (Tyson 2003), a weight ratio needed for the above N_{JS} (Harnby et al 1992).

D_{imp} is not known until the tank is sized

The volume excluding the upper, dished head is:

$$V_{tank} := 8000\,gal$$

$$V_{tank} = V_{barr} + V_{bot}$$

According to Perry's (Perry & Green 1984), a standard head has volume:

$$V_{bot} = 0.05D^3 + 1.65\cdot\zeta\cdot D^2$$

$\zeta := \frac{3}{8}in$ (Determined at meeting 3/10/04)

Try an aspect ratio of barrel height to diameter of 1 (note the hot shop has head space of about 40 ft and the entrance door is about 30 ft):

$$\frac{h_{barr}}{D} = 1$$

$$V_{tank} = \frac{\pi}{4} \cdot D^3 + \left(0.05 \cdot D^3 + 1.65 \cdot \zeta \cdot D^2\right)$$

Find D by trial & error

$D_{tk} := 10.84ft$ $\qquad$ $V_{chk} := \frac{\pi}{4} \cdot D_{tk}^{\ 3} + \left(0.05 \cdot D_{tk}^{\ 3} + 1.65 \cdot \zeta \cdot D_{tk}^{\ 2}\right)$

$V_{chk} = 8.005 \times 10^3 \, gal$

guess h_{bot} formula as:

$h_{barr} := D_{tk}$ $\qquad$ $h_{bot} := \frac{V_{tank}}{\pi \cdot D_{tk}^{\ 2}}$ $\qquad$ $h_{bot} = 2.897ft$

$D_{imp} := \frac{D_{tk}}{3}$ $\qquad$ $D_{imp} = 3.613ft$

The clearance (λ/D) is: $\qquad$ $\lambda_{bot} := \frac{D_{tk}}{4}$ $\qquad$ $\lambda_{bot} = 2.71ft$

$$N_{JS} := \frac{S_m \cdot \nu^{0.1} \cdot d_p^{\ 0.2} \cdot \left(g \cdot \frac{\Delta\rho}{\rho_L}\right)^{0.45} \cdot \chi^{0.13}}{D_{imp}^{\ 0.85}} \qquad N_{JS} = 58.645 \frac{1}{min}$$

*The N_{JS} is the minimum speed to suspend particles

$P_o = \frac{P}{\rho \cdot N^3 \cdot D_{imp}^{\ 5}}$ $\qquad$ $P_{ow} := P_o \cdot \rho_L \cdot N_{JS}^{\ 3} \cdot D_{imp}^{\ 5}$ $\qquad$ $P_{ow} = 0.507hp$

At this point the information was provided to the vendor (Chemineer and Lightnin). Chemineer provided a design for the system based on this information and is included in Appendix C. Also, the electrical is designed to handle up to 5 h.p. so it was decided to use this power to suspend higher than the mmpd.

From the power number:

$$P_{ow\_act} := 5\,hp \qquad N_{act} := 68\frac{Rev}{min} \qquad \text{(rpm from vendor)}$$

The torque produced by the shaft/impeller motion is:

$$T_{orq} = \vec{r} \times \vec{F} = \vec{r} \times m\cdot\frac{d}{dt}\vec{v} \qquad v = \omega \cdot r \qquad T_{orq} = \vec{r} \times \vec{F} = \frac{\vec{v}}{\omega} \times m\cdot\frac{d}{dt}\vec{v}$$

$$T_{orq} = \frac{P_{ow} \cdot SF}{N \cdot g_c} \qquad g_c := 9.8\frac{kg\cdot m}{kgf\cdot s^2}$$

$$T_{orq} := \frac{P_{ow\_act}}{N_{act}\cdot g_c} \qquad T_{orq} = 386.4\ ft\cdot lbf$$

The force resulting from the torque is:

$$F_s := 1.5 \qquad r := \frac{D_{tk}}{2} \qquad F_r := \frac{P_{ow\_act}\cdot F_s}{N_{act}\cdot r} \qquad F_r = 106.9 lbf$$

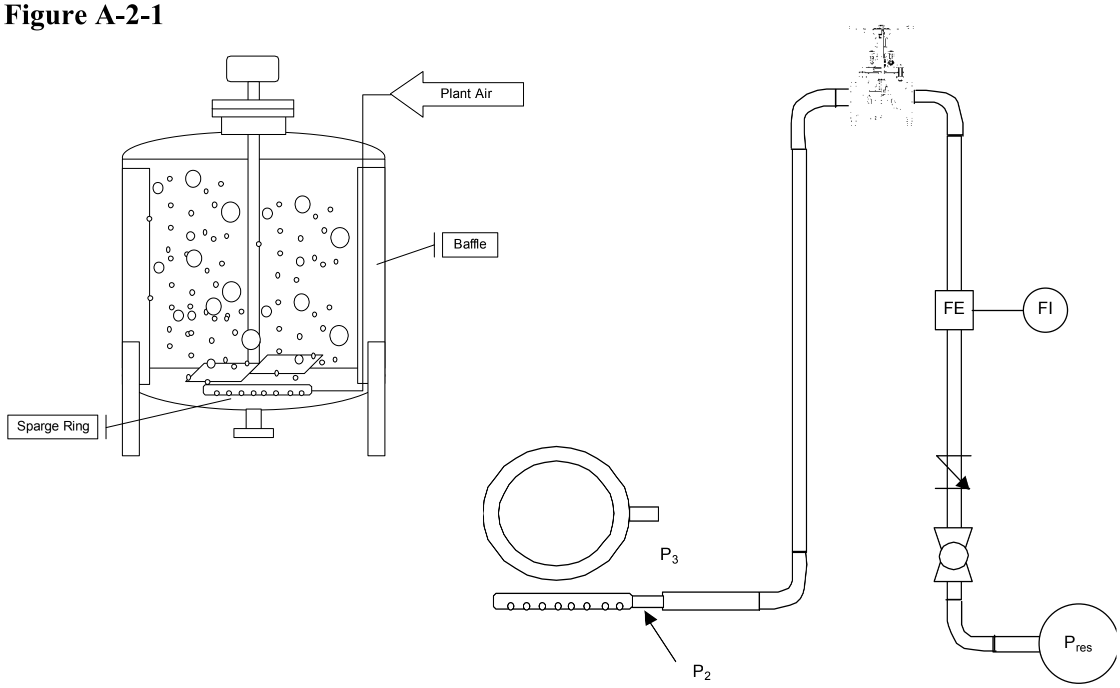
This force will be a reaction with the floor friction and the angle welds.

Find the total height of the tank (Figure A-2-1) assuming a bottom clearance of 1.5 ft and top appurtenances of 3 ft.

$$h_{tot} := 2\cdot h_{bot} + 1.5ft + 3ft + h_{barr} \qquad h_{tot} = 21.134\ ft$$

A sparge ring will go directly below the agitator impeller as shown below (1/2 distance from impeller to tank bottom). This distance is 1/2 the distance between the impeller and the tank bottom.

Figure A-2-1



The orifice discharge pressure is about 8 ft, (8 ft depth of liquid in a tank)

(Note, MathCad doe not distinguish between gage and actual pressures)

$\rho_{liq} := 1.0 \frac{kg}{L}$ $\qquad P_{actual} := \rho_{liq} \cdot g \cdot 8ft$ $\qquad P_{actual} = 3.468psi$

$P_{stand} := 14.7\,psi$ $\qquad T_{air} := 298K$

Set the hole diameter to 1/8" (this also sets the bubble diameter estimate). Treybal (Treybal 1987) says to orient the holes on the top. However, it has been determined that orientation doesn't matter (Oldshue 1983). In fact, hole size or orientation makes little difference in the area where the mixer flow pattern prevails, i.e., this is because the impeller controls the dispersion and the bubbles produced by the sparge ring are not controlling. Therefore, it was decided to orient the holes on the bottom to prevent solids from falling into them and plugging once the air is turned off.

$d_o := \frac{1}{8} in$ $\qquad D_{pipe} := 1in$

Set n to get Re_o turbulent (e.g., > 2000), Treybal says to use 10^4 but not required (Treybal 1987).

$n := 50$

The maximum available air is 192 scfm, specify 150 scfm total, 50 scfm/tank.

$Q_{air} := 50 \frac{ft^3}{min} \cdot \frac{P_{stand}}{P_{actual} + P_{stand}}$ $\qquad Q_{air} = 40.455 \frac{ft^3}{min}$

$v_{air} := \frac{Q_{air}}{\frac{\pi}{4} \cdot D_{pipe}^2}$ $\qquad \mu_g := 1812 \cdot 10^{-7} poise$ $\qquad$ (Perry et al 1984)

$v_{orf} := v_{air} \cdot \frac{D_{pipe}^2}{n \cdot d_o^2}$ $\qquad v_{orf} = 158.236 \frac{ft}{s}$

$MW_{air} := 29 \frac{gm}{mol}$ $\qquad R_g := 0.0821 \frac{L \cdot atm}{mol \cdot K}$

$\rho_{air} := \frac{P_{actual} \cdot MW_{air}}{R_g \cdot T_{air}}$ $\qquad \rho_{air} = 0.28 \frac{kg}{m^3}$

$Re_o := \frac{d_o \cdot v_{orf} \cdot \rho_{air}}{\mu_g}$ $\qquad Re_o = 2.364 \times 10^3$

The tank superficial velocity v_g is:

$v_g := \frac{Q_{air}}{\frac{\pi}{4} \cdot D_{tk}^2}$ $\qquad v_g = 7.306 \times 10^{-3} \frac{ft}{s}$

Since this is less than the upper limit given by Treybal ($v_g < 0.25$ ft/s), it is OK.

$D_{ring} := \frac{7}{8} \cdot D_{imp}$ $\qquad$ (Optimum is 80% according to Oldshue)

The center-to-center hole spacing is about:

$n_{space} := D_{ring} \cdot \frac{\pi}{n}$ $\qquad n_{space} = 2.38$ in

NOMENCLATURE

g_c	Gravity conversion
g	Gravity acceleration
D_{tk}	Tank diameter
D_{imp}	Impeller diameter
d_o	Bubble (hole) diameter
d_p	Particle diameter
D_p	Pipe diameter
F_s	Torque agitator factor
h	Height
n	Hole number
N	Speed
N_{js}	Speed for incipient suspension
P	Pressure
P_o	Power number
P_{ow}	Power
Q	Flow rate
Re	Reynolds number
R_g	Gas constant
S_m	Mixer Parameter
T	Temperature
T_{orq}	Torque
v	Velocity

Greek

$\Delta\rho$	Density difference
ζ	Thickness
λ	Clearance
μ	Viscosity
ν	Kinematic viscosity
ρ	Density
χ	Weight ratio

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Appendix A-3

Recirculation Pump Design and Calculations

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Appendix A-3, Recirculation Pump Design and Calculations

The criteria is to provide 50 gpm at 60 psi at the pump discharge for using one of the pumps for flushing and to provide particle suspension velocity or 100 gpm at recirculation head conditions. The first criterion was requested by mechanical to provide V-Tank flushing flow and pressure. Recirculation head conditions are the head losses from recirculating the liquids back into the tanks.

$g := 9.8\frac{m}{s^2}$ $\rho := 1\frac{kg}{L}$ $D_{tk} := 10.5ft$

$H_1 := \frac{60 \cdot psi}{\rho \cdot g}$ $H_1 = 138.4ft$

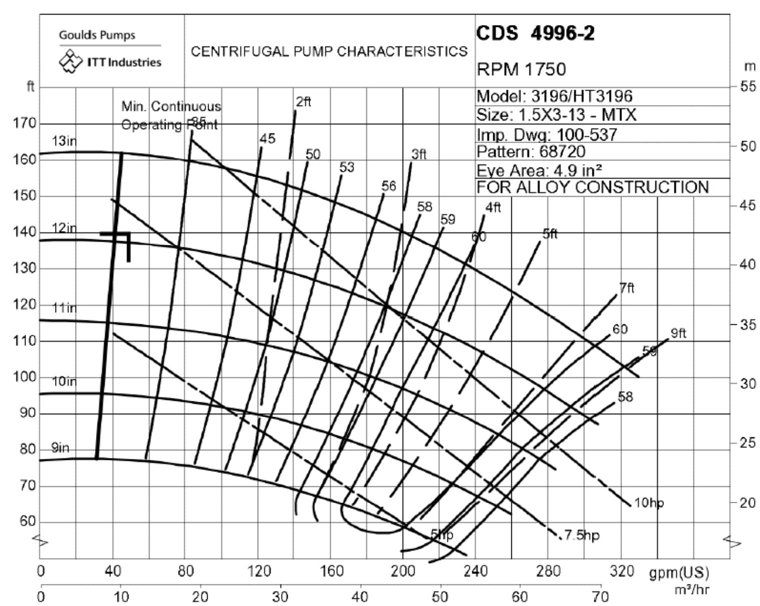
Check horsepower

$Q_1 := 50\frac{gal}{min}$ $m_{dot\_1} := Q_1 \cdot \rho$ $\varepsilon_{eff} := 0.5$

$P_{ow\_1} := \frac{-H_1 \cdot g \cdot m_{dot\_1}}{\varepsilon_{eff}}$ $P_{ow\_1} = -3.5hp$

An examination of vendor pumps indicates that the Gould solids-handling model works for this (see Appendix C). The pump curve in Figure A-3-1 shows that the 7.5 - 10 hp model works.

Figure A-3-1



Determine the particle suspension flow and head.

Assume friction losses for fittings are 50% of pipe friction loss.

The bulk, superficial velocity in the tank is:

$v = \frac{Q}{A_c}$ $\qquad A_c := \frac{\pi}{4} \cdot D_{tk}^2$ $\qquad A_c = 86.59\ ft^2$

The sedimentation velocity using Stokes Law (de Nevers 1970) is:

$S_s := 1.46$ $\qquad S_L := 1$ $\qquad d_p := 144 \cdot 10^{-6} m$

(The above data were determined in the report body and Appendix A-3)

$\mu := 0.01 \cdot poise$ $\qquad \nu := \frac{\mu}{\rho}$

$v_s := \frac{g}{18\nu} \cdot (S_s - S_L) \cdot d_p^2$ $\qquad v_s = 0.017 \frac{ft}{s}$

$Q_{sed} := v_s \cdot A_c$ $\qquad Q_{sed} = 662.625 \frac{gal}{min}$ This is the amount required to suspend the mmpd particle. However, target value is 100 gpm or larger.

The flow can be varied to match the 7.5 hp by trial and error. This provides an approximation and determines if the minimum can be met. Vary Q_{targ} until match P_{ow} = 7.5 hp.

$Q_{targ} := 260 \frac{gal}{min}$

Use Bernoulli's equation to size pumps assuming 2 inch pipe $\qquad D_{pipe} := 2in$

The average velocity is Q/A.

$v := \dfrac{Q_{targ}}{\dfrac{\pi}{4}\cdot D_{pipe}^{2}}$ $v = 26.552\dfrac{ft}{s}$

The following is a modification of Bernoulli's to include pumps (de Nevers, 1970)

$$\Delta\left(\frac{P}{\rho}\cdot g_c + g\cdot z + \frac{v^2}{2}\right) = \frac{d}{dm}W_{ao} - \Phi$$

$\Phi = 4\cdot f\cdot\dfrac{1.5\,L}{D_{p2}}\cdot\dfrac{v^2}{2}$ $\varepsilon_{rough} := 0.0457mm$

$Re_n := \dfrac{D_{pipe}\cdot\rho\cdot v}{\mu}$ $Re_n = 4.111\times 10^{5}$ $\dfrac{\varepsilon_{rough}}{D_{pipe}} = 8.996\times 10^{-4}$

Finding f for steel pipes: $f := 0.0045$

The length, L, is about 20 ft from the tank outlet to the top so the friction is found as:

$L_n := 20ft$

$\Phi_n := 4\cdot f\cdot\dfrac{1.5\,L_n}{D_{pipe}}\cdot\dfrac{v^2}{2}$ $\Phi_n = 35.499\dfrac{ft\cdot lbf}{lb}$

All of the Δ's except g*z are zero since the flow is from free surface to free surface, the Δz is assumed about 10 ft (use 20). The work is (de Nevers 1970):

$-W = \dfrac{d}{dm}W_{ao} = \Delta z\cdot g_n + \Phi$ $\Delta z := 20\,ft$

$W_n := -\left(g\cdot\Delta z + \Phi_n\right)$ $W_n = -55.485\dfrac{ft\cdot lbf}{lb}$

The pressure is: $P_2 := -W_n\cdot\rho$ $P_2 = 24.054\ psi$

$H_2 := \dfrac{P_2}{\rho\cdot g}$ $H_2 = 55.485\ ft$

The horse power is the mass rate times the work:

$$m_{dot2} := Q_{targ} \cdot \rho \qquad m_{dot2} = 2.17 \times 10^{3} \frac{lb}{min}$$

$$P_{ow\_2} := \frac{W_n \cdot m_{dot2}}{\varepsilon_{eff}} \qquad P_{ow\_2} = -7.297hp$$

It is believed that the pump chosen can deliver 260 gpm but this is off the pump curve and can't be guaranteed. However, it can get at least 100 gpm and will likely require throttling for process feed. The suspension velocity cannot be matched at this flow so the agitator needs to be the primary suspension device. The larger particles will accelerate upon exiting the tank bottoms but will slip (i.e. settle faster than the superficial velocity) in the tanks but be suspended via agitation.

NOMENCLATURE

A_c	Tank cross sectional area
g_c	Gravity constant
g	Gravity acceleration
D_{tk}	Tank diameter
d_p	Particle diameter
D_{pipe}	Pipe diameter
f	Friction factor
H	Head
m_{dot}	Mass rate
P	Pressure
P_{ow}	Power
Q	Flow rate
Re	Reynolds number
S	Specific gravity
v	Velocity
V	Volume
W	Work
$W_{a.o.}$	Work excluding injection work
z	Elevation

Greek

$\Delta\rho$	Density difference
ε_{eff}	Efficiency
ε_{rough}	Roughness
μ	Viscosity
ν	Kinematic viscosity
ρ	Density
Φ	Friction work

REFERENCES

de Nevers, N., Fluid Mechanics, Addison-Wesley, 1970.

Appendix B

Corrosion and Materials Charts

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Table B-1, Ozone Resistance of Selected Materials.[a]

Material	Theoretical rating (Cole Parmer) [Ozone Concentrations not specified]	Practical rating (by Ozone Services) [Ozone Concentrations up to 100mg/l]
304 stainless steel	B - Good	C
316 stainless steel	A - Excellent	B
ABS plastic	B - Good	D
Acetal (Delrin®)	C - Fair	C
Aluminum	B - Good	C
Brass	N/A	C
Bronze	B - Good	C
Buna N (Nitrile)	D - Severe Effect	DD
Carbon graphite	N/A	
Carpenter 20	N/A	
Cast iron	N/A	
Ceramic Al203	N/A	
Ceramic magnet	N/A	
Copper	A - Excellent	C
CPVC	A - Excellent	B
EPDM	A - Excellent	B
Epoxy	N/A	
Hastelloy-C®	N/A	
Hypalon®	A - Excellent	C
Hytrel®	C - Fair	C
Kel-F®	A - Excellent	?

Table B-1. (continued).

Material	Theoretical rating (Cole Parmer) [Ozone Concentrations not specified]	Practical rating (by Ozone Services) [Ozone Concentrations up to 100mg/l]
LDPE	C1 - Fair	B
Natural rubber	D - Severe Effect	DD
Neoprene	C - Fair	B
NORYL®	N/A	
Nylon	D - Severe Effect	D
Polycarbonate	A1 - Excellent	B
Polypropylene	B - Good	C
PPS (Ryton®)	N/A	
PTFE (Teflon®)	A - Excellent	AA
PVC	B - Good	C
PVDF (Kynar®)	A - Excellent	AA
Silicone	A - Excellent	A
Titanium	N/A	
Tygon®	N/A	
Viton®	A - Excellent	A

a. http://www.o3zone.com/articles/003.htm.

Table B-2. Corrosion Resistance.

TechInfo
BEN MEADOWS COMPANY

Corrosion & Chemical Resistance: A Guide to Common Materials

Document Number: 164
Page: 1 of 2

This chart lists the compatibility of materials with many common workplace chemicals. The information is believed to be accurate. However, the chart is for general use only, and is not a guarantee of chemical compatibility. Ben Meadows can assume no responsibility for the use of this information. Variations in temperature, pressure or concentration may affect the chemical resistance of a material.

CHEMICAL	LDPE	HDPE	PP	PVC	TEFLON*	NYLON	BUNA-N	VITON	ALUMINUM	CARBON STEEL	STAINLESS STEEL 316	STAINLESS STEEL 304
Acetic acid, glacial	B	A	B	D	A	D	C	D	A	D	A	C
Acetone	D	D	A	D	A	A	D	D	A	A	A	A
Acetonitrile	A	A	C	D	A	nt	D	D	B	A	A	A
Acrylonitrile	A	A	C	D	A	A	D	D	B	A	A	A
Alcohols:												
Amyl	A	A	nt	nt	A	A	B	B	B	B	A	A
Benzyl	D	C	D	C	A	D	D	A	B	B	A	A
Ethyl	B	A	B	C	A	A	C	A	B	B	A	A
Hexyl	B	B	nt	nt	A	A	A	A	A	A	A	A
Isobutyl	A	A	A	C	A	A	B	A	B	nt	A	A
Isopropyl	A	A	A	C	A	B	B	A	B	A	A	A
Methyl	A	A	A	C	A	A	A	B	A	A	A	A
Aluminum Hydroxide	B	A	B	B	A	A	A	A	B	nt	C	A
Ammonium Chloride	nt	A	nt	nt	A	C	B	A	C	D	D	C
Ammonium Hydroxide	B	A	B	C	A	A	D	B	B	D	A	A
Amyl Acetate	C	B	C	D	A	C	D	D	A	B	A	A
Amyl Chloride	D	C	D	D	A	C	nt	B	A	A	A	A
Aniline	B	B	C	D	A	C	D	C	C	B	B	A
Benzaldehyde	B	A	B	D	A	C	D	D	B	A	B	B
Benzene	D	D	D	D	A	A	D	A	B	A	B	B
Bromine	D	D	D	D	A	D	D	A	D	D	D	D
Butadiene	D	D	D	D	A	A	D	B	A	A	A	A
Butyric Acid	D	D	D	D	A	B	D	B	B	D	B	B
Calcium Hydroxide	A	A	A	B	A	A	A	A	C	C	B	C
Calcium Hypochlorite	A	A	A	D	A	C	C	A	D	D	B	C
Chloroform	D	D	D	D	A	D	D	A	B	B	A	B
Cresols	D	D	C	D	A	D	D	A	A	A	A	A
Cyclohaxane	D	D	D	D	A	A	A	A	A	B	A	A
Cyclohexanone	D	D	D	D	A	A	nt	D	A	B	A	A
Diethylamine	D	D	C	D	A	A	C	D	B	A	B	nt
Diethylene Glycol	A	A	A	D	A	A	A	A	B	nt	A	A
Ethyl Acetate	A	A	A	D	A	A	D	D	B	A	B	B
Ethylene Glycol	A	A	A	D	A	B	A	A	B	A	A	A
Fatty Acids	B	A	B	B	A	A	B	A	A	D	A	B
Formaldehyde 40%	B	A	B	D	A	C	B	A	B	A	A	A
Gasoline	D	B	C	D	A	A	A	A	A	A	A	A
Heptane	D	C	C	D	A	A	A	A	A	A	A	A
Hexane	D	C	C	D	A	A	A	A	A	A	A	A
Hydrazine	D	D	D	D	A	nt	B	A	nt	D	A	A
Hydrochloric acid, 20%	A	A	A	B	A	D	nt	A	D	D	D	D
Hydrochloric acid, 100%	nt	nt	nt	D	nt	D	D	A	D	D	D	D
Hydrofluoric acid, 20%	A	A	A	A	nt	C	B	A	D	D	D	D
Hydrofluoric acid, 100%	nt	nt	nt	nt	nt	D	D	A	D	D	B	B
Hydrogen peroxide,30%	B	A	B	C	A	D	nt	A	A	nt	B	B
Isopropyl acetate	C	B	C	D	A	B	D	D	B	B	A	C
Kerosene	D	B	C	D	A	A	A	A	A	A	A	A
Mercury	A	A	A	C	A	A	A	A	nt	A	A	A
Methyl Acetate	D	C	C	D	A	A	D	D	A	A	A	A
Methyl Ethyl Ketone	D	D	B	D	A	A	D	D	A	A	A	A
Methylene Chloride	D	D	D	D	A	C	D	B	A	B	B	B

Table B-2. (continued).

TechInfo
BEN MEADOWS COMPANY

Corrosion & Chemical Resistance:
A Guide to Common Materials

Document Number: 164
Page: 2 of 2

CHEMICAL	LDPE	HDPE	PP	PVC	TEFLON*	NYLON	BUNA-N	VITON	ALUMINUM	CARBON STEEL	STAINLESS STEEL 316	STAINLESS STEEL 304
Mineral Spirits	D	D	D	D	A	A	A	A	A	nt	A	A
Nitric acid, 50%	D	D	D	D	A	D	D	A	C	D	A	A
Nitrobenzene	D	D	D	D	A	B	D	B	A	B	A	B
Phosphoric acid, >40%	A	A	B	C	A	B	D	A	B	D	B	A
Potassium Hydroxide, 80%	A	A	A	C	A	C	B	B	D	nt	B	B
Propylene Glycol	A	A	A	C	A	nt	A	A	B	A	B	B
Silver Nitrate	B	A	B	B	A	A	B	A	D	D	B	B
Sodium Hydroxide, 80%	B	C	A	C	A	C	B	B	D	D	C	B
Sodium Hypochlorite, <20%	A	A	C	C	A	D	B	A	D	D	C	C
Sulfuric acid, <10%	A	A	A	B	A	C	D	A	D	D	B	D
Sulfuric acid, 10-75%	B	A	B	D	A	D	D	A	D	D	D	D
Sulfuric acid, 75-100%	B	B	C	D	A	D	D	A	D	D	D	C
Tetrachloroethane	nt	nt	nt	D	nt	C	D	A	C	A	A	B
Tetrachloroethylene	nt	nt	nt	D	nt	A	D	A	nt	A	A	nt
Toluene	D	B	C	C	A	A	D	A	A	A	A	A
Trichloroethane	D	D	D	D	B	C	D	A	C	B	A	B
Trichloroethylene	D	D	D	D	A	C	C	A	A	D	B	B
Xylene	C	C	D	D	A	A	D	A	A	B	A	A

A=EXCELLENT
B=GOOD
C=FAIR
D=NOT RECOMMENDED
nt=NO TEST DATA AVAILABLE

Table B-3, Plastic Advantages and Disadvantages.

Insulation Types	Advantages	Disadvantages
FEP and PTFE (Dupont ™ Teflon)	• Excellent high temperature properties. PTFE Teflon is preferred for solder applications. FEP is preferred for jacket material. • Non-flammable • Good outgassing characteristics • Most flexible of all insulations • Good weatherability, resists moisture absorption and atomic oxygen erosion	• Susceptible to cold flow when stressed (bent) over tight radius or when laced too tightly. • Degraded by solar radiation above 5 x 10^5 RADS. • FEP has poor cut through resistance • Heaviest insulation

Table B-3. (continued).

Insulation Types	Advantages	Disadvantages
ETFE (Dupont ™ Tefzel)	• Withstands physical abuse during and after installation • Good high and low temperature properties • High flex life • Good outgassing characteristics • Fair cold flow properties	• Some ETFE insulations fail flammability in a 30% oxygen environment • Insulation tends to soften at high temperature • Degraded by gamma radiation above 10^6 RADS

Crosslinked ETFE (Dupont ™ Tefzel)	• Higher strength than normal ETFE
	• Resistant to cold flow and abrasion
	• More resistant to radiation effects (to 5 x 10^7 RADS)
	• Higher maximum temperature than normal ETFE
	  ○ Tin Coating = 150°C Max.
	  ○ Silver Coating = 200°C Max.
	• Good outgassing characteristics
		• Some ETFE insulations fail flammability in a 30% oxygen environment
		• Less flexible than extruded ETFE
		• More difficult to work with than PTFE Teflon

Aromatic Polyimide (Dupont ™ Kapton)	• Lightest weight wire insulation material. Commonly used with FEP or PTFE Teflon to form layered insulation tapes • Excellent physical thermal and electric properties. Excellent cut-through resistance and cold flow resistance • Excellent radiation resistance (to 5 x 10^9 RADS) • Good outgassing characteristics	• Inflexibility - difficult to strip. • Absorbs moisture. Degraded by atomic oxygen. Poor weatherability • Prone to wet-arc and dry-arc tracking from abrasions and cuts • More difficult to flex • Not stable to ultraviolet radiation
Crosslinked Polyalkene	• Dual extrusion which is fused by sintering. Combines excellent abrasion and cut through resistance of Polyvinylidene Fluoride (PVDF, PVF_2- Penwalt Corp. ™ Kynar) with Polyolefin for greater flexibility and	• Lower maximum conductor temperature rating ○ (135°C for GSFC S-311-P-13)

Table B-3. (continued).

Insulation Types	Advantages	Disadvantages
	improved heat resistance. Polyalkene is used mainly as a primary insulation under an outer jacket such as crosslinked ETFE or crosslinked PVDF/PVF_2 • High dielectric constant, used in high voltage applications • PVDF has good radiation resistance (to 10^8 RADS) • More resistant to cold flow • Good outgassing characteristics	○ (150°C for MIL-W-81044) • Reduced flexibility
Silicon Rubber	• Excellent flexibility at low temperatures • Excellent high voltage corona resistance • Good radiation resistance (to 10^8 RADS) • Good cold flow resistance	• Poor cut through resistance, mechanical toughness, and fluid resistance • Must be processed for outgassing control • Flammable • No standard silicon rubber insulated wire or cable

Appendix C

Vendor Information

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Goulds Pumps
ITT Industries

CH SPENCER and COMPANY
C.H. SPENCER and COMPANY
Power Plant and Industrial Equipment

1075 South Pioneer Road
Salt Lake City, Utah 84104

ph: 801-975-0300 ext. 108
fx: 801-972-5216

INEEL

Proposal No: INEEL042904
Item No: ITEM003

May 6, 2004
Attn: SAM ASHWORTH

MODEL:3196 Size: 1.5x3-13 MTX QTY: 1

Operating conditions

SERVICE	
LIQUID	*Water Temp. 160.0 deg F, SP.GR 1.000 , Viscosity 1.000 cp*
CAPACITY Norm./Rate	*50.0 / 50.0 gpm*
HEAD	*140.0 ft*

Performance at 1750 RPM

PUBLISHED EFFY	*24.5% (CDS)*
RATED EFFY	*23.0% with contract seal*
RATED POWER	*7.7 hp (incl. Mechanical seal drag 0.39). (Run out 12.8 hp)*
NPSHR	*0.2 (ft)*
DISCH. PRESSURE	*60.6 (61.0 @ Shut off) (psi g)*
PERF.CURVE	*4996-2 (Rotation CW viewed from coupling end)*
SHUT OFF HEAD	*140.8 ft*
MIN FLOW	*41.5 (gpm)*

PRICES in USD	
Pump Unit	8,267
Driver	323
Boxing	
Testing	
Freight	
Accessories	
Total 1 Unit	8,590
Shipment: 12-14 WKS FOB NY	

Materials

CONSTRUCTION	*CD4MCU*
CASING	*CD4MCU max.casing.pres.@ rated temp.273.7psi g*
ST.BOX COVER	*CD4MCU*
IMPELLER	*CD4MCU - Open (12.1250 rated (in) max=13.0000 min=9.0000)*
CASING GASKET	*Aramid Fiber with EPDM Rubber*
IMPELLER O-RING	*Teflon*
SHAFT	*316SS*
SHAFT SLEEVE	*None*
LUBRICATION	*Flood oil*
SEAL CHAMBER	*Taper bore plus with VPE*
GLAND	*316SS Barrier in and out*
BEARINGS	*SKF 6309 (Inboard Bearing) SKF 5309 A/C3 (Outboard Bearing)*
COUPLING	*T.B. Wood's-SC 6-*
COUPLING GUARD	*Carbon steel*
BASEPLATE	*Fabricated steel flexibly mounted D03826A01*

Sealing Method

MECHANICAL SEAL	*John Crane - 5620PR - XO(58)1O(58)H/XF(55)1O(58)H - (Cartridge-Double)*

Flanges
150# flat face

Liquid end features
Impeller balance holes
Impeller single plane balanced to ISO G6.3

Frame features
Ductile iron frame adapter

.../

Piping

CPI Plan 7354 No piping furnished by Goulds
Safematic/safeunit compact sealing control system

Painting

Goulds Blue water reducible coating (Strathmore)

Optional Features:

Baseplate Type

Fabricated steel to ANSI B73.1M 1991 (over Fabricated steel flexibly mounted) **deduct** 10

All above optional adders are per unit in (USD)

Driver: Electric motor Manufacturer: Pump mfg 's Choice

FURNISHED BY	*Pump mfg*	MOUNTED BY	*Pump mfg*
RATING	*10.0 hp (7.5 KW)*	ENCLOSURE	*TEFC "Epact Efficient"*
PHASE/FREQ/VOLTS	*3/60 Hz/230/460*	SPEED	*1800 RPM*
INSULATION/SF	*F/1.15*	FRAME	*215T*

Weights and Measurements

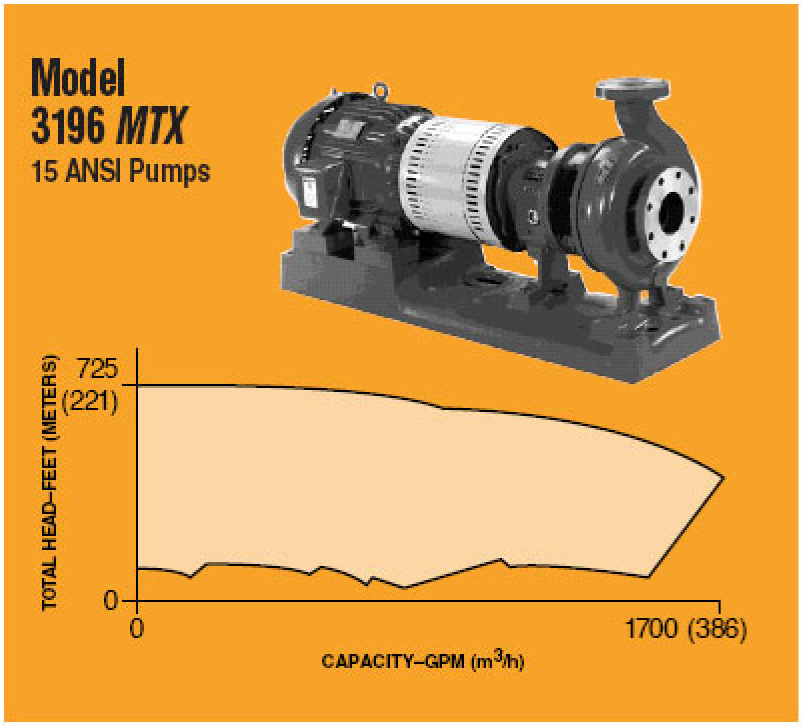
TOTAL NET UNIT WEIGHT/VOLUME	*560.0lb*	/ *11.4ft3*
TOTAL GROSS UNIT WEIGHT/VOLUME	*662.0lb*	/ *20.4ft3*

Comments

NOTE: SPRING LOADED BASE PLATES ARE GENERALLY USED ON LARGER, HEAVIER PUMPS. WHEN USED ON SMALLER PUMPS, SUCH AS THIS PUMP, VIBRATIONS THAT ARE SUPPOSEDLY BEING CONTROL ARE IN ACTUALLITY INCREASED. GOULDS RECOMMENDS A FLEXIBLY MOUNTED BASE INSTEAD OF A SPRING LOADED BASE FOR THIS PUMP. IF YOU REQUIRE THE SPRING LOADED BASE, PLEASE LET ME KNOW AND I WILL BE GLAD TO OFFER A QUOTATION ADDER. ALSO INCLUDED IN THIS PROPOSAL IS A FABRICATED STEEL BASE FOR YOUR CONSIDERATION.

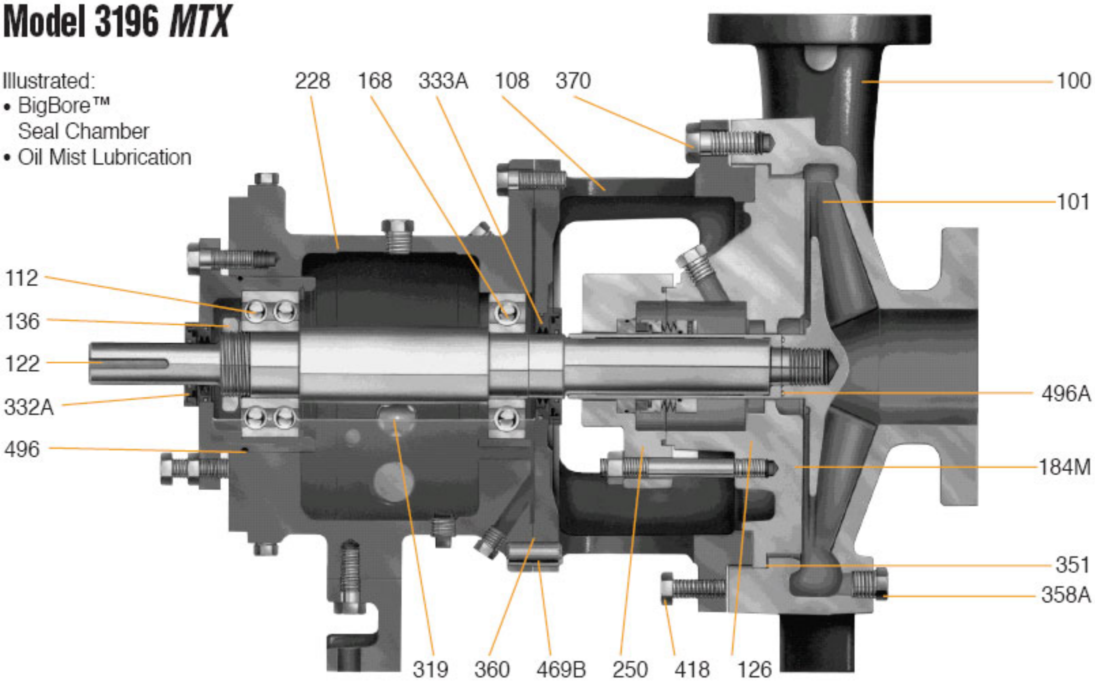
Program Version 2.7.0.0

Our offer does not include specific review and incorporation of any Statutory or Regulatory Requirements and the offer is limited to the requirements of the design specifications. Should any Statutory or Regulatory requirements need to be reviewed and incorporated then the Customer is responsible to identify those and provide copies for review and revision of our offer.



Model 3196 *MTX*

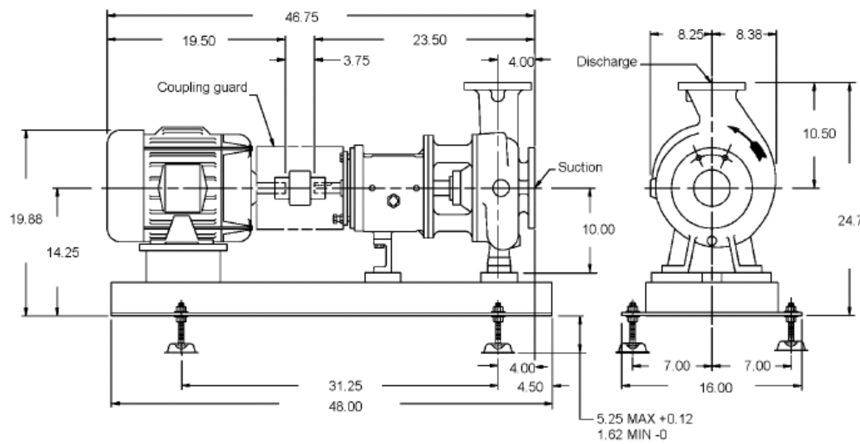
Illustrated:
- BigBore™ Seal Chamber
- Oil Mist Lubrication



Goulds Pumps
ITT Industries

OUTLINE DRAWING

**Model 3196 MTX
1.5x3-13**



Pump specification

SUCT.FLANGE SIZE *3"*	DRILLING *ANSI 150#*	FACING *FF*	FINISH *SERRATED*
DISCH.FLANGE SIZE *1.5"*	DRILLING *ANSI 150#*	FACING *FF*	FINISH *SERRATED*
PUMP ROTATION (LOOKING AT PUMP FROM MOTOR) *CW*			
TYPE OF LUBRICATION *FLOOD OIL*			COOLED *NO*
TYPE OF STUFFING BOX *TAPER BORE PLUS WITH VPE*			COOLED *NO*
TYPE OF SEALING *MECHANICAL SEAL*			

Weights and Measurements

PUMP	*265.0 lb*
MOTOR/CPLG	*160.0/8.0 lb*
BASEPLATE	*127.0 lb*
TOTAL	*560.0 lb*
GR.VOLUME w/BOX	*20.4 ft3*
GR.WEIGHT w/BOX	*662.0 lb*

Motor specification

MOTOR BY *PUMP MFG* MOUNT BY *PUMP MFG*	MFG. *PUMP MFG 'S CHOICE*	
FRAME *215T*	POWER *10.0 hp*	RPM *1800*
PHASE *3*	FREQUENCY *60 Hz*	VOLTS *230/460*
INSULATION *F*	S.F. *1.15*	
ENCLOSURE *TEFC "EPACT EFFICIENT"*		

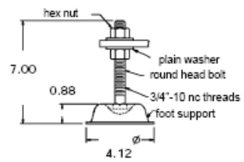
Notes and References

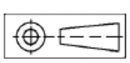
* MTR DIMENSIONS ARE APPROXIMATE

FOR PUMP TAPPED OPENINGS REFER TO DWG.:
TINEEL042904/ITEM003

Auxiliary specification

COUPLING BY *PUMP MFG*	CPLG TYPE *T.B. WOOD'S SC 6*
CPL GUARD BY *PUMP MFG.*	CPLG GUARD MATL *CARBON STEEL*
BASEPLATE *FABRICATED STEEL FLEXIBLY MOUNTED D03826A01*	
MECH.SEAL *JOHN CRANE 5620PR XO(58)1O(58)H/XF(55)1O(58)H*	





DRAWING IS FOR REFERENCE ONLY.
NOT CERTIFIED FOR CONSTRUCTION UNLESS SIGNED.

Customer: INEEL
Serial No:
Customer P.O. No:
Item No: ITEM003
Service:

All dimensions are in inches.
Drawing is not to scale
Weights (lbs) are approximate

DRAWING NO INEEL042904/ITEM003

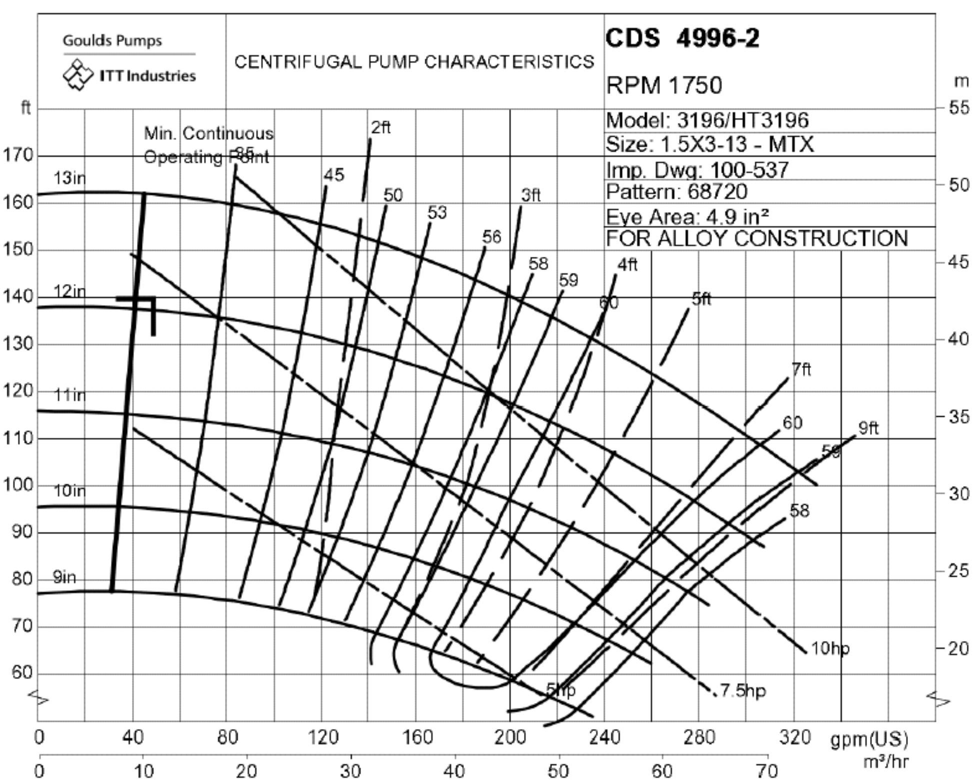
FORM # ED0050 ED0741 Program Version 2.7.0.0

Model:3196/HT3196 Size:1.5X3-13 Group:MTX 60Hz RPM:1750 Stages:1

Job/Inqu. No.					
Purchaser:					
User:		Issued by:	GORDON CANTRELL		
Item/Equip.No:		Quotation No.		Date:	4/29/04
Service:		Order No.		Certified By:	

Operating Conditions			**Pump Performance**		
Liquid:	Water	Actual Pump Eff.:	24.5 %	Suction Specific Speed:	8503 (gpm(US) , ft)
		Actual Pump Power:	7.1 hp	Min. Cont. Stable Flow:	42 gpm(US)
Temp.:	160 °F	Mech. Seal Loss:	0 hp	Min. Cont. Thermal Flow:	
Sp. Heat:		Dyn. Seal Loss:	0 hp		
S.G./Visc.:	1/1 cp	Other Power Loss:	0 hp	Non-Overloading Power:	12.1 hp
Flow:	50 gpm(US)	Rated Total Power:	7.1 hp	Imp. Dia. Addt'l Stg	
TDH:	140 ft	Imp. Dia. First 1 Stg	12.125 in		
NPSHa:		NPSHr:	2 ft	Mag. Drive Circuit Flow:	
Req. solid size:		Shut off Head:	140.8 ft	Max Drive Power:	
% Solids:		Max. Solids Size:	0.219 in	Max Drive Temp:	
Vapor Press:				Max Motor Size:	

Notes: 1. The Mechanical seal increased drag effect on power and efficiency is not included, unless the correction is shown in the appropriate field above. 2. Magnetic drive eddy current and viscous effect on power and efficiency is not included. 3. Elevated temperature effects on performance are not included.



Mechanical Sealing Systems

Safeunit™ order form

Safeunit™ type:
Type SFP
Type SFQ
Type SFD

Flow:
3 l/min (0,75 GPM)
8 l/min (2 GPM)
15 l/min (4 GPM)

Pressure area:
10 bar (150 psi)
25 bar (360 psi)

Complete hose assembly:
Yes

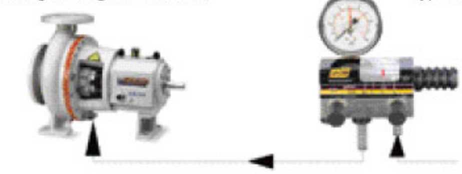
Seal connections:

NPT	1/8	1/4	3/8
R	1/2	Other	

Documentation:
English
German
Swedish
Other ________________________

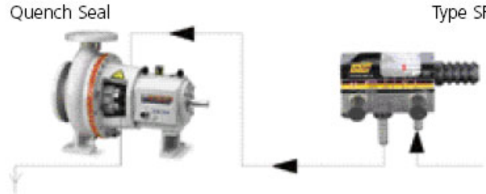
Packing or single Seal Flush

Type SFP



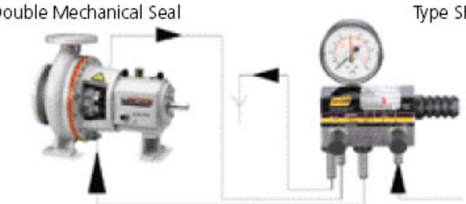
Quench Seal

Type SFQ



Double Mechanical Seal

Type SFD



Mounting:

Bracket

Stand

Alarm:
AC-1 (20-250 VAC/DC)
DC-1 (10-36 VDC)

Europe
Slough, UK
Tel: 44-1753-224000
Fax: 44-1753-224224

Latin America
São Paulo, Brazil
Tel: 55-11-3371-2500
Fax: 55-11-3371-2599

Middle East, Africa, Asia
Dubai, United Arab Emirates
Tel: 971-4-3438940
Fax: 971-4-3438970

North America
Morton Grove, Illinois USA
1-800-SEALING
Tel: 1-847-967-2400
Fax: 1-847-967-3915

smiths

For your nearest John Crane facility, please contact one of the locations above.

If the products featured will be used in a potentially dangerous and/or hazardous process, your John Crane representative should be consulted prior to their selection and use.
In the interest of continuous development, John Crane Companies reserve the right to alter designs and specifications without prior notice. It is dangerous to smoke while handling products made from PTFE. Old and new PTFE products must not be incinerated.

 Print 10/03 **www.johncrane.com** ISO 9001, ISO 14001, ISO/TS 16949, QS-9000 Certified. **B-Safeunit/Eng**

Safematic Safeunit™

Complete monitoring and control solution for seals and seal water systems

Installing the Safeunit™ seal water system will ensure trouble free operation of process machinery in all conditions and achieve the maximum life cycle profit of your investment.

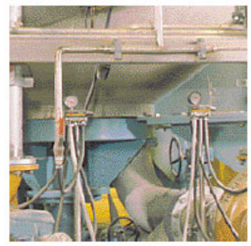
Adjusting the seal water flow and pressure with Safeunit will create the best possible operating environment for seals and maximize the runnability of the process.

Save Seal Water

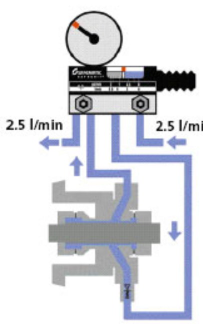
2 drops/second = 14 m³ / year

Safeunit seal water system dramatically reduces water consumption by up to 80%. This means a considerable drop in waste water load.

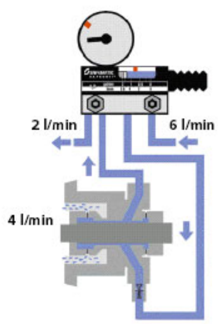
For example, with the water price of US $0.50/m3, the annual savings in a mill with 300 pumps is US $300,000 (flow reduction 4 l/min/pump).



Normal operation



Flow increases and pressure decreases

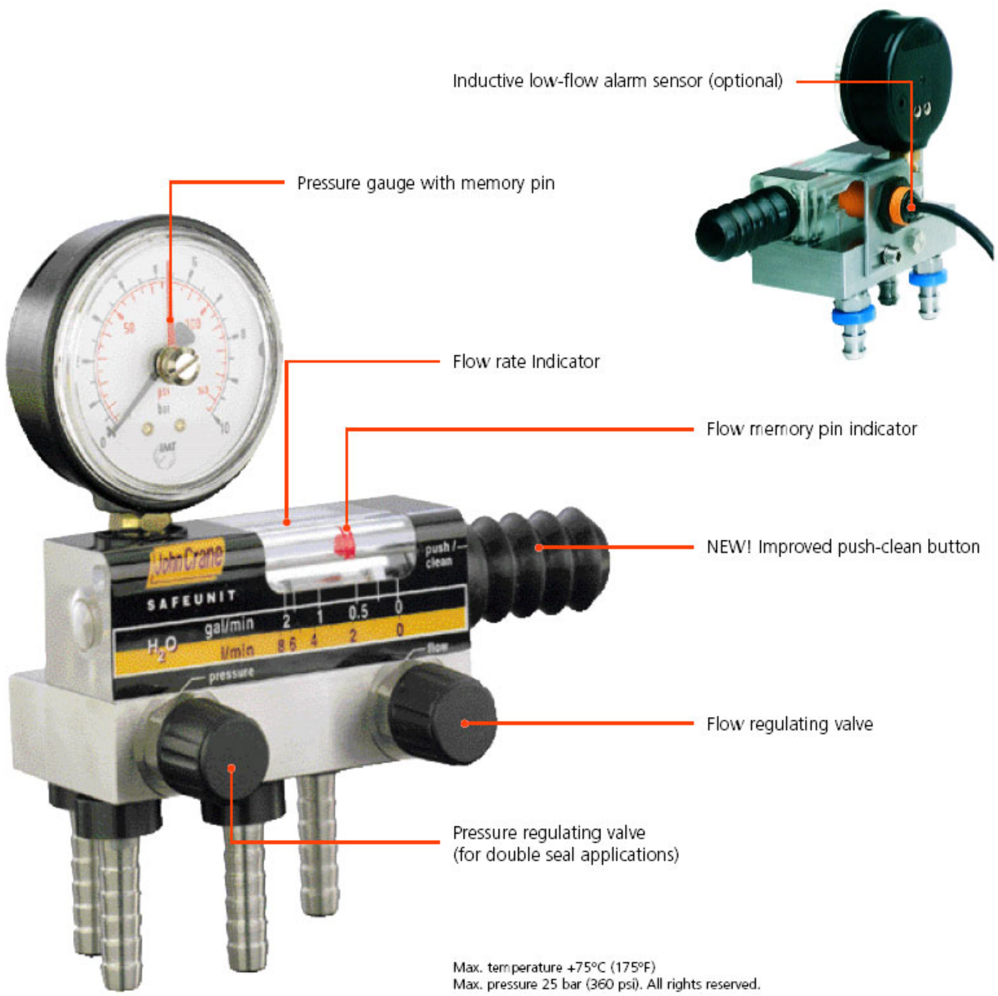


Changes in the pre-set system values for flow and pressure will indicate any possible problems in seals and system well in advance. For automatic control, alarm sensors can be used.

Safeunit system also detects seal water leakage in the process resulting in extra heating and evaporation costs or expensive quality problems such as dilution.

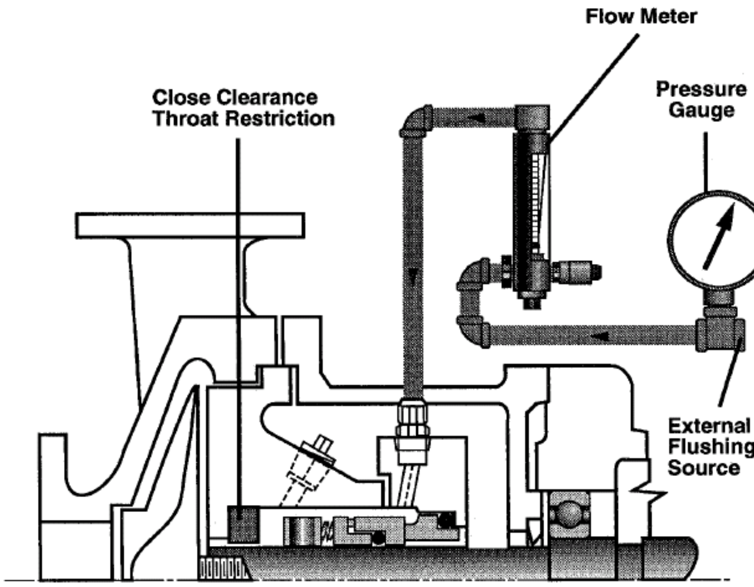
User friendly, compact unit

- Controls and monitors seal water flow and pressure
- Predicts seal and packing failures
- Reduces and pre-determines maximum seal water consumption
- Can be cleaned with equipment running. Alarm will not go off with the new improved push-clean button
- Simplifies pump setup and service
- Detects and locates seal water line problems
- Flow indicator and pressure gauge with memory pin
- Unique non-clog valves
- Available with optional electrical alarms and LCS-leakage control system



Max. temperature +75°C (175°F)
Max. pressure 25 bar (360 psi).

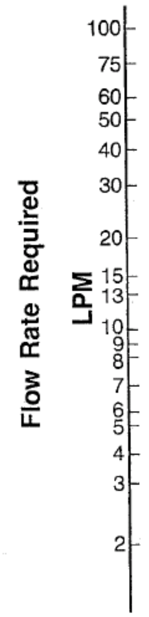
Flush From External Source
Single Inside Seal



API Plan 32
ANSI Plan 7332

This system works well but is generally misunderstood.
THE FLUSH FLUID ENTERS THE PRODUCT.
If that is unacceptable, plan 32 should not be used.

Flow I
15 ft/s



Agitator

04/14/04 11:14a — Chemineer Agitator Design System — v5.53r

Customer	: INEEL	**Customer PO.**	:
Quote No.	: 510R-SAN-04	**Cust. Ref**	: Suspension Tank
No of Units	: 1	**Cust. EQ #**	:

Fluid:	**Viscosity**	1.00 cp	**Pressure**		0.00 PSIG
	Specific Gravity	1.00	**Temperature**		160.00 F
Solids:	**Solids Specific Gravity**	1.40	**Slurry Specific Gravity**		1.02
	Solids by Weight	8.00%	**Solids by Volume**		5.85%
	Particle TSV	0.84 ft/min	**Particle Diameter**		0.144 mm
Comments:					
Nozzle:	**Bending moment**	5033 ft-lbs	**Tank:**	**Mtg height**	8.00 in
	Reaction Torque	959 ft-lbs		**Top head type**	Flat
Weight:	**Total Mounted**	1496 lbs		**Top head depth**	0.00 in
	Approx. Ship	1671 lbs		**Btm head type**	ASME
Baffles:	**Number**	4		**Btm head depth**	20.80 in
	Width	10.0 in		**Diameter**	120.00 in
	Clearance	1.7 in		**Straight side**	163.20 in
	Length	163.2 in		**Liquid Volume**	8000 gal

Model Number	3GTA-5	**Motor Power**	5.00 HP
RPM of Unit	68.0	**Service Rating**	Class III

Drive Features:
Drive Mounting: Vertical & On-Center; Gearbox Dip Stick: Included
Pedestal Hand Hole Cvrs: Included; Base Paint System: Sherwin-Williams Polane HS Plus
Drive Cplg - Lower Half: Taper Bore Removable (Steel); Gear Drive Lubrication: Splash

Motor: Q09040-391O **Furnished by:** Chemineer **Mounted by:** Customer

Motor Features:
Power: 5.00 HP; Speed: 1800 RPM; Frame: NEMA 180TC; Voltage: 230/460V; Phase: 3
Frequency: 60 Hz; Efficiency: High; Service Duty: Chemical; Enclosure: TEFC
Service Factor: 1.15; Insulation Class: F; Ambient Temperature: Maximum 40C
Temperature Rise: NEMA Class B (80C); Motor Mount: C-Face

Motor Options:
Motor Vendor: Chemineer's Choice; Drip Cover: Included; Motor Paint: Motor Manufacturer's Std
Flexible Cplg Supplied: Woods Sureflex

Shaft/Impellers:

Shaft Diameter	3.0 in	**Shaft/Cplg Mat'l:**	CS (Steel)
Shaft Extension	162.0 in	**Impeller Mat'l:**	CS (Steel)

	Diameter	**Type**	**Ext Frm Mtg**
#1	49.00 in	SC3	162.0 in

Blades are Welded to Hub
Wetted Parts are covered with 1/4" Other/Chemineer applied
Covering is only applied to wetted parts below mounting flange

Mounting Features:
Flange Rating: 150#; Flange Material: Carbon Steel; Flange Size: 10"; Flange Face: Raised
Flange Construction: Solid

04/14/04 11:14a Chemineer Agitator Design System v5.53r

Customer	: INEEL	**Customer PO.**	:
Quote No.	: 510R-SAN-04	**Cust. Ref**	: Suspension Tank
No of Units	: 1	**Cust. EQ #**	:

Seal Features:
Style Pressure Limit: GTA = 100 PSIG; Seal Material: C1065 Packing; Split Gland Material: 316

Negotiated Delivery:	5-6 wks		
Unit Sell Price:	$15,050	**Number of Units:**	1
Total Sell Price:	$15,050	**FOB:**	Ship Point

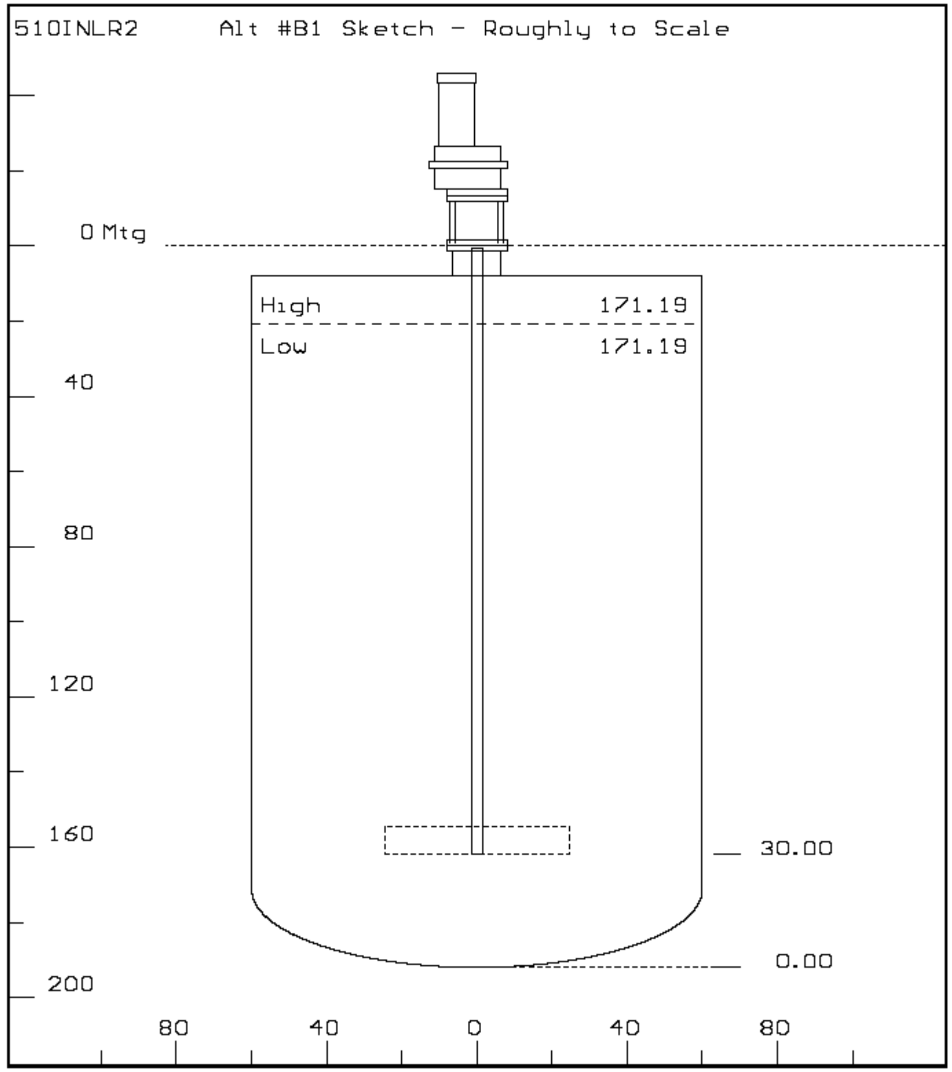
INEEL
Suspension Tank
Quote No: 510R-SAN-04
3GTA-5@68

Tank	
Tank Volume:	8627
Diameter:	120.00
S Side:	163.20
Flat Top:	0.00
ASME Bot:	20.80
Mtg Ht:	8.00
Total Height	192.00

Process	
Slurry S.G.:	1.02
Viscosity:	1
Hi Lvl Vol:	8000
Temperature:	160
Pressure:	0
ChemScale:	5

Shaft	
Material:	CS
Diameter:	3.0
Extension:	162.0

Impellers		
Material:		CS
49.00	SC3@	162.0

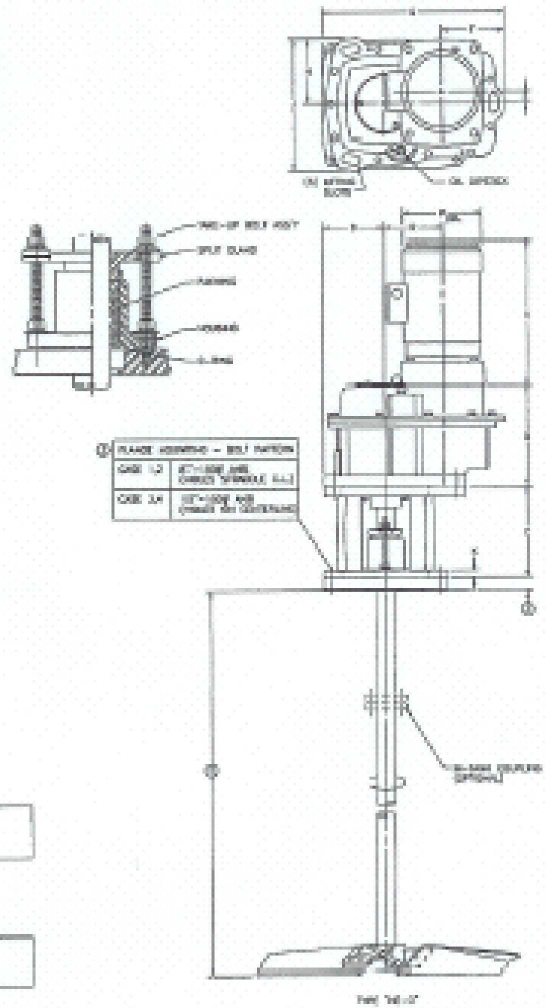


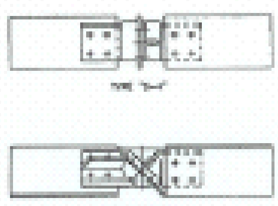
AgDesign (02/02/04) Copyright 1992-2004 by Chemineer, Inc. Version: 5.53r

Chemineer

MOTOR DIMENSIONS (MAX) (1750 RPM)			
H.P.	FRAME	A ①	P ①
1, 1-1/2, 2	145TC	16"	8"
3, 5	182TC	20"	10"
7-1/2, 10	215TC	23"	12"
15, 20	256TC	31"	14"
25, 30	286TC	34"	15"

CASE SIZE	1 & 2	3 & 4
B	10-7/8"	13-1/8"
C	10"	12-1/2"
D	8-3/4"	8-1/2"
E	1-1/4"	2-3/8"
F	6-13/16"	8-1/8"
G	19-7/8"	24-1/2"
H	8-7/8"	8-3/8"
J	13-3/4"	17"
K	3/4"	7/8"
R	6-5/16"	7-7/8"





① DIMENSIONS ARE FOR TOTALLY ENCLOSED AND EXPLOSION-PROOF MOTORS.

② AGITATOR OUTPUT SPEED, SHAFT DIAMETER & EXTENSION, IMPELLER DESIGN AND OTHER OPTIONAL FEATURES TO SUIT APPLICATION.

③ OPTIONAL FLANGE SIZES ARE AVAILABLE.

DIMENSION SHEET
MODEL GTA
CA-551
REF. BULLETIN
SERIES 700

Maestro - Mixing Advisor V2.02r - (c) 2004 Chemineer , Inc.

```
Wid  - 120.0 in
SS   - 163.2 in
B Hd - ASME   20.8 in
T Hd - Flat   0.0 in
Z    - 171.19 in
Vol  - 7999.89
```

```
Process Information
Density  - 1.0
Visc     - 1.0
Fl Inx n - 1.0
T        - 160.0
P        - 14.5
```

```
Impeller Data
1 49.0 in SC-3
```

	T(in)	Motor	P(HP)	Load (%)	RPM	Imp. 1	CS	Info
1	120.00	5.HP	3.72	74%	68.3	SC-3	5-6	OK

(1) No process design errors detected. Evaluate the mechanical and economical feasibility using CEDS or the manuals.

```
Solid Suspension
Solid Density - 1.4
TSV           - 0.84
Weight %      - 8.00

Njs           - 405.0%
```

```
Blendtime
  80%  0:00:22
  85%  0:00:26
  90%  0:00:31
  95%  0:00:41
  98%  0:00:54
  99%  0:01:03
```

```
Gas Dispersion
```

==
Maestro V2.02r - (c) 2004 Chemineer Inc. Page 1/1
==
Customer: INEEL
Reference: Suspension Tank
User: SARGEANT
Date/Time: 5/4/2004 9:18:52 AM
Tank Diameter: 120.00 inch
Bottom Depth: 20.80 inch
Liquid Level: 171.19 inch
Viscosity: 1.00 cP
SG: 1.00
RPM: 68.3
Motor: 5.0 HP
==
49.0SC-3@30.0
==
==
Maestro V2.02r - (c) 2004 Chemineer Inc. Page 2/3
==
==
Style Nb D (inch) Wb OffBot P/D Angle Pump
==
1 SC-3 3 49.00 11.25 30.00 Down
==
Style Nb Pu(HP) Pu(%) Pg(HP) Pg(%) Pg/Pu
==
1 SC-3 3 3.724 100.00
0.466 HP/1000-US-Gallon Ungassed
Maximum Newtonian viscosity before overload
at given liquid density = 8.262E+02cP
==
Style Nb D/T W/D C/T Re Fr Po Flg
==
SC-3 3 0.408 0.23 0.25 1.763E+06 0.164 0.62
The Flow is Turbulent
==
==
Maestro V2.02r - (c) 2004 Chemineer Inc. Page 1/3
==
Customer: INEEL
Reference: Suspension Tank
User: SARGEANT
Date: 5/4/2004
Time: 9:18:52 AM
==

Tank Information
==
Diameter (inch): 120.0
Straight Side (inch): 163.2
Bottom Style: ASME
Bottom Depth (inch): 20.8
Head Style: Flat
Head Depth (inch): 0.0
Liquid Level (inch): 171.19
Volume (US Gal): 7999.89
Shaft Diameter (inch): 3.00
Shaft Off Bottom (inch): 30.0
Number Of Baffles: 4
Baffle Style: Regular Flat
Baffle Width (inch): 10.0
Baffle Off Wall (inch): 1.67
Baffle Off Bottom (inch): 5.0
Baffle Off Top (inch): 0
==
Process Information
==
Specific Gravity: 1.0
Viscosity at 1/s (cP): 1.0
Flow Index n: 1.0
Yield Stress (Dyne/cm^2): 0.000E+00
Newtonian Fluid
Temperature (°F): 160.0
Absolute Pressure (psi): 14.5
==
Drive Information
==
Motor (HP): 5.00
Motor (kW): 3.73
Max Motor Load (%): 85.0
Actual Motor Load (%): 74.5
Speed (rpm): 68.3
Speed (1/s): 1.1383
Seal Type: None (Open Tank, HTD/HTP)
Wetted Parts Material: Carbon Steel
Mounting Height (inch): 8.0
==

==

Maestro V2.02r - (c) 2004 Chemineer Inc. Page 3/3

==

Liquid Blending Chemscale: 5-6

==

BLEND TIME
Addition Specific Gravity:
Addition Viscosity (cP\mPas):
Blend time - No Significant Effect Of Addition

==

Uniformity Hours Minutes Seconds
80 % 0 0 22
85 % 0 0 26
90 % 0 0 31
95 % 0 0 41
98 % 0 0 54
99 % 0 1 3
99.9 % 0 1 35

==

Suspension - Uniform Suspension

==

Solids Specific Gravity: 1.4
Particle Diameter (mm): 0.144
Particle Free Set. Vel. (ft/min): 0.84
Hindered Set. Vel. (ft/min): 0.73
Weight Percent: 8.00
Volume Percent: 5.85
Slurry Specific Gravity: 1.02
RPMjs: 16.9
Njs (1/s): 0.28
RPM/RPMjs: 4.05
Unsuspended (%): 0 %
Cloud Height: 95%-100%
Main Impeller: 1 - SC-3
Scale-up based on particle free settling velocity.

==